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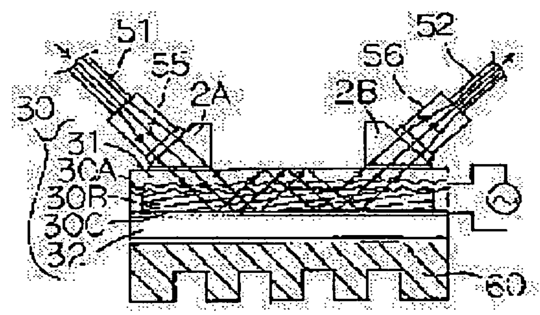
(54) LIQUID CRYSTAL OPTICAL DEVICE AND ILLUMINATOR USING THE SAME

(57)Abstract:
PURPOSE: To provide an efficient optical modulator.
CONSTITUTION: This liquid crystal optical device is provided with optical fibers 51 and 52, rod lenses 55 and 56, prisms 2A and 2B, and a liquid crystal optical element 30 consisting of a front substrate 31, a front electrode 30A, a liquid crystal solidified composite layer 30B, a rear electrode 30C used as a reflecting means, and a rear substrate 32, and a sufficient gap between substrates is reserved to a rugged boundary face in the optical path or the liquid crystal solidified composite layer or a boundary face inclined at an angle α to the reflecting face is provided, and light passes the liquid crystal solidified composite layer 30B twice or more.



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CLAIMS

[Claim(s)]
[Claim 1] Between the light source, the first light guide means, the first prism object, the front substrate with which the front electrode was formed, and the flesh-side substrate with which the flesh-side electrode was formed The liquid crystal solidification object complex with which distributed maintenance of the liquid crystal was carried out into the solidification object matrix is pinched. Light is scattered about, in case liquid crystal is controlled by the electric field generated between two electrodes and the refractive index of liquid crystal is not in agreement with the refractive index of a solidification object matrix. The liquid crystal optical element equipped with the liquid crystal solidification object complex layer which light penetrates when the refractive index of liquid crystal was mostly in agreement with the refractive index of a solidification object matrix, A light reflex means, the second prism object, and the second light guide means are established. A light reflex means is arranged in the middle of the optical path from the light source to the second light guide means. [whether a liquid crystal solidification object complex layer approaches the reflector side of a light reflex means, and is arranged, and] Or stick to a reflector and are arranged, and the light by which outgoing radiation was carried out from the light source passes the first light guide means, and it carries out incidence inside a liquid crystal optical element from the incidence section of the first field of a liquid crystal optical element through the first prism object. It is reflected once or more with the first reflective section or light reflex means of a field, respectively, and outgoing radiation is carried out to the last from the outgoing radiation section of the first field. Furthermore, incidence is carried out to the second light guide means through the second prism object. By the time it results [from the incidence section] in the outgoing radiation section, it is 2n about a liquid crystal solidification object complex layer. Time (n= 1 or more integers) passage is carried out. [whether irregularity is prepared in at least one interface in the interface which the quantity of light is controlled by the transmittance of the light of a liquid crystal solidification object complex layer in this case, and crosses the optical path inside a liquid crystal optical element, and] Or the spacing d of the liquid crystal solidification object complex layer of a liquid crystal optical element, and a light reflex means [whether it considers as 10 or more times to thickness t of a liquid crystal solidification object complex layer, and] Or liquid crystal optical equipment characterized by making at least one interface in the interface which crosses the optical path inside a liquid crystal optical element incline only at the predetermined include angle alpha to the reflector of a light reflex means.
[Claim 2] Between the light source, the first light guide means, the front substrate with which the front electrode was formed, and the flesh-side substrate with which the flesh-side electrode was formed The liquid crystal solidification object complex with which distributed maintenance of the liquid crystal was carried out into the solidification object matrix is pinched. Light is scattered about, in case liquid crystal is controlled by the electric field generated between two electrodes and the refractive index of liquid crystal is not in agreement with the refractive index of a solidification object matrix. The liquid crystal optical element equipped with the liquid crystal solidification object complex layer which light penetrates when the refractive index of liquid crystal was mostly in agreement with the refractive index of a solidification object matrix, A light

reflex means, the second light guide means, and the prism object equipped with the reflector are established. A light reflex means is arranged in the middle of the optical path from the light source to the second light guide means. [whether a liquid crystal solidification object complex layer approaches the reflector side of a light reflex means, and is arranged, and] Or stick to a reflector, it is arranged and the light by which outgoing radiation was carried out from the light source is made to pass the first light guide means. A light guide is carried out inside a prism object from the plane of incidence of a prism object, and incidence is further carried out inside a liquid crystal optical element from the incidence section of the first field of a liquid crystal optical element. It is reflected once or more with the reflector or light reflex means of a prism object, respectively. By the time it finally carries out incidence to the second light guide means from the outgoing radiation side of a prism object and reaches [from the plane of incidence of a prism object] the outgoing radiation side of a prism object, it is 2n about a liquid crystal solidification object complex layer. Time (n= 1 or more integers) passage is carried out. [whether irregularity is prepared in at least one interface in the interface which the quantity of light is controlled by the transmittance of the light of a liquid crystal solidification object complex layer in this case, and crosses the optical path inside a liquid crystal optical element, and] Or the spacing d of the liquid crystal solidification object complex layer of a liquid crystal optical element, and a light reflex means [whether it considers as 10 or more times to thickness t of a liquid crystal solidification object complex layer, and] Or liquid crystal optical equipment characterized by making at least one interface in the interface which crosses the optical path inside a liquid crystal optical element incline only at the predetermined include angle alpha to the reflector of a light reflex means.

[Claim 3] Liquid crystal optical equipment characterized by forming irregularity in the interface which a front electrode makes in the liquid crystal optical equipment with which irregularity was prepared in the interface of claims 1 or 2.

[Claim 4] Liquid crystal optical equipment characterized by forming irregularity in the interface which a flesh-side electrode makes in the liquid crystal optical equipment with which irregularity was prepared in the interface of any 1 term of claims 1-3.

[Claim 5] It is liquid crystal optical equipment characterized by coming to use a light reflex means also [electrode / almost flat / of a liquid crystal optical element / flesh-side] in the liquid crystal optical equipment with which irregularity was prepared in the interface of any 1 term of claims 1-3.

[Claim 6] Liquid crystal optical equipment characterized by forming a heat regulator in a flesh-side substrate side further in the liquid crystal optical equipment of any 1 term of claims 1-5.

[Claim 7] The lighting system equipped with the liquid crystal optical equipment of any 1 term of claims 1-6.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] This invention relates to the liquid crystal optical equipment using the liquid crystal optical element of the transparency dispersion mold equipped with an optical fiber and liquid crystal solidification object complex, and the lighting system using it.
[0002]
[Description of the Prior Art] A liquid crystal optical element is arranged between the light source and the optical fiber for optical transmissions from the former, and the liquid crystal optical equipment which controls the quantity of light transmitted to an optical fiber from the light source by the liquid crystal optical element is known. Furthermore, the lighting system and luminous-intensity-distribution equipment using the optical fiber bundle, the light source, and the liquid crystal optical element which bundled the optical fiber for optical energy transmissions or the optical fiber of single track are proposed.
[0003] Moreover, an optical fiber is used for the light guide means from the light source to a liquid crystal optical element, and the configuration which has arranged the liquid crystal optical element between optical fibers is proposed. The basic arrangement is shown in drawing 6 as a conventional example. It consists of liquid crystal optical elements 30 which show the mode of operation of the transparency dispersion mold equipped with the optical fiber 51 for incidence, the optical fiber 52 for outgoing radiation, a convex lens 41, and a reflective mold means and liquid crystal solidification object complex. And this configuration can attain the modulation of light.
[0004] Moreover, although it is the arrangement configuration which resembled this conventional example, the optical variable attenuator which used the low loss thin line optical fiber for optical-communication information transmissions for the optical optical incidence [of a liquid crystal optical element] and outgoing radiation side is proposed. As mentioned above, since reduction of optical loss is attained by using the liquid crystal optical element equipped with the liquid crystal solidification object complex which has the mode of operation of a transparency dispersion mold, and can control light without a polarizing plate, even if it uses a high-reflective-liquid-crystal optical element and a lens, it is proposed that optical variable attenuator can be built.
[0005]
[Problem(s) to be Solved by the Invention] In this case, in order that light may pass a liquid crystal solidification object complex layer twice by considering as the configuration of a reflective mold, the scattering power of the liquid crystal solidification object complex itself improves by leaps and bounds compared with the configuration of the transparency mold which light passes once.
[0006] However, in order for a part of interface reflection produced in the interface of a liquid crystal optical element, the interface of the lens for condensing, etc. to always carry out incidence to the optical fiber by the side of optical outgoing radiation, when liquid crystal solidification object complex was in a dispersion condition, the outgoing radiation quantity of light from an optical fiber did not become low, and the extinction ratio of the outgoing radiation light by the electrical-potential-difference impression to a liquid crystal solidification object complex

layer and un-impressing was not able to say that it was high compared with the configuration of a transparency mold.
[0007] Therefore, the dynamic range of the quantity of light change accompanying the electrical-potential-difference seal of approval of a liquid crystal optical element hardly improved as compared with the component configuration of a transparency mold, and it was still a low characteristic value. Moreover, when the light source which emits a lot of light was used, the temperature rise of the liquid crystal optical element accompanying the radiant heat etc. was remarkable, the repeatability of various kinds of electro-optics properties (the property of applied-voltage pair light transmittance, a dynamic response characteristic, extinction ratio, etc.) became low, and exact modulated light became difficult.
[0008]
[Means for Solving the Problem] This invention between the light source, the first light guide means, the first prism object, the front substrate with which the front electrode was formed, and the flesh-side substrate with which the flesh-side electrode was formed The liquid crystal solidification object complex with which distributed maintenance of the liquid crystal was carried out into the solidification object matrix is pinched. Light is scattered about, in case liquid crystal is controlled by the electric field generated between two electrodes and the refractive index of liquid crystal is not in agreement with the refractive index of a solidification object matrix. The liquid crystal optical element equipped with the liquid crystal solidification object complex layer which light penetrates when the refractive index of liquid crystal was mostly in agreement with the refractive index of a solidification object matrix, A light reflex means, the second prism object, and the second light guide means are established. A light reflex means is arranged in the middle of the optical path from the light source to the second light guide means. [whether a liquid crystal solidification object complex layer approaches the reflector side of a light reflex means, and is arranged, and] Or stick to a reflector and are arranged, and the light by which outgoing radiation was carried out from the light source passes the first light guide means, and it carries out incidence inside a liquid crystal optical element from the incidence section of the first field of a liquid crystal optical element through the first prism object. It is reflected once or more with the first reflective section or light reflex means of a field, respectively, and outgoing radiation is carried out to the last from the outgoing radiation section of the first field. Furthermore, incidence is carried out to the second light guide means through the second prism object. By the time it results [from the incidence section] in the outgoing radiation section, it is 2n about a liquid crystal solidification object complex layer. Time (n= 1 or more integers) passage is carried out. [whether irregularity is prepared in at least one interface in the interface which the quantity of light is controlled by the transmittance of the light of a liquid crystal solidification object complex layer in this case, and crosses the optical path inside a liquid crystal optical element, and] Or the spacing d of the liquid crystal solidification object complex layer of a liquid crystal optical element, and a light reflex means [whether it considers as 10 or more times to thickness t of a liquid crystal solidification object complex layer, and] Or the liquid crystal optical equipment (1) characterized by making at least one interface in the interface which crosses the optical path inside a liquid crystal optical element incline only at the predetermined include angle alpha to the reflector of a light reflex means is offered.
[0009] Moreover, between the light source, the first light guide means, the front substrate with which the front electrode was formed, and the flesh-side substrate with which the flesh-side electrode was formed The liquid crystal solidification object complex with which distributed maintenance of the liquid crystal was carried out into the solidification object matrix is pinched. Light is scattered about, in case liquid crystal is controlled by the electric field generated between two electrodes and the refractive index of liquid crystal is not in agreement with the refractive index of a solidification object matrix. The liquid crystal optical element equipped with the liquid crystal solidification object complex layer which light penetrates when the refractive index of liquid crystal was mostly in agreement with the refractive index of a solidification object matrix, A light reflex means, the second light guide means, and the prism object equipped with the reflector are established. A light reflex means is arranged in the middle of the optical path from the light source to the second light guide means. [whether a liquid crystal solidification

object complex layer approaches the reflector side of a light reflex means, and is arranged, and] Or stick to a reflector, it is arranged and the light by which outgoing radiation was carried out from the light source is made to pass the first light guide means. A light guide is carried out inside a prism object from the plane of incidence of a prism object, and incidence is further carried out inside a liquid crystal optical element from the incidence section of the first field of a liquid crystal optical element. It is reflected once or more with the reflector or light reflex means of a prism object, respectively. By the time it finally carries out incidence to the second light guide means from the outgoing radiation side of a prism object and reaches [from the plane of incidence of a prism object] the outgoing radiation side of a prism object, it is 2n about a liquid crystal solidification object complex layer. Time (n= 1 or more integers) passage is carried out. [whether irregularity is prepared in at least one interface in the interface which the quantity of light is controlled by the transmittance of the light of a liquid crystal solidification object complex layer in this case, and crosses the optical path inside a liquid crystal optical element, and] Or the spacing d of the liquid crystal solidification object complex layer of a liquid crystal optical element, and a light reflex means [whether it considers as 10 or more times to thickness t of a liquid crystal solidification object complex layer, and] Or the liquid crystal optical equipment (2) characterized by making at least one interface in the interface which crosses the optical path inside a liquid crystal optical element incline only at the predetermined include angle alpha to the medial axis of an optical path is offered.
[0010] Moreover, in the liquid crystal optical equipment with which irregularity was prepared in the interface of above liquid crystal optical equipment (1) or (2), the liquid crystal optical equipment (3) characterized by forming irregularity in the interface which a front electrode makes is offered. Moreover, in the liquid crystal optical equipment with which irregularity was prepared in any one interface of above liquid crystal optical equipment (1) - (3), the liquid crystal optical equipment (4) characterized by forming irregularity in the interface which a flesh-side electrode makes is offered.
[0011] Moreover, in the liquid crystal optical equipment with which irregularity was prepared in any one interface of above liquid crystal optical equipment (1) - (3), the liquid crystal optical equipment (5) characterized by coming to use a light reflex means also [electrode / almost flat / of a liquid crystal optical element / flesh-side] is offered. Moreover, in any one liquid crystal optical equipment of above liquid crystal optical equipment (1) - (5), the liquid crystal optical equipment (6) characterized by forming a heat regulator in a flesh-side substrate side further is offered. Furthermore, the lighting system equipped with any one liquid crystal optical equipment of above liquid crystal optical equipment (1) - (6) is offered.
[0012] In the liquid crystal optical equipment of this invention, detailed irregularity is formed in the transparent electrode side of a liquid crystal optical element as an unnecessary normal reflected light reduction means, or spacing d of the liquid crystal solidification object complex layer of a liquid crystal optical element and a light reflex means is made into 10 or more times to thickness t of a liquid crystal solidification object complex layer. Whenever [tilt-angle] is prepared for the liquid crystal solidification object complex layer of a liquid crystal optical element to the reflector of a light reflex means. The component which carries out incidence to the second light guide means among the normal reflection produced with these unnecessary reflective reduction means in the interface of a liquid crystal solidification object complex layer and substrate glass with a transparent electrode etc. is reduced.
[0013] Moreover, one-structure is adopted and a compact and the liquid crystal optical equipment which was optically [firmly and] excellent mechanically are offered so that the normal reflected light by the interface between a prism object and a liquid crystal optical element may be controlled positively.
[0014]
[Function] In order that according to this invention light may pass only through the inside of a solid-state medium and may pass a liquid crystal solidification object complex layer twice [at least] or more, the effectual scattering power of a transparency dispersion mold optical element improves. And when the liquid crystal optical element of a transparency dispersion mold is installed between the light source and an optical fiber with a reflective mold configuration,

degradation of the extinction ratio and dynamic range resulting from interface reflection of each optical element which poses a problem is improved. Consequently, a high extinction ratio is obtained compared with the optical equipment using the transparency dispersion mold liquid crystal optical element and optical fiber of the conventional transparency mold component configuration and a reflective mold component configuration.

[0015] Moreover, while the electro-optics property of a liquid crystal optical element is stabilized, it can be made to always operate at the temperature from which the optimal electro-optics property is acquired by carrying out temperature control of the liquid crystal optical element compulsorily from a flesh-side substrate side.

[0016]

[Example]

(Example 1) An example explains concretely hereafter. The example 1 of this invention is shown in drawing 1 , and it explains with reference to this. The light guide of the light by which outgoing radiation was carried out from the light source installed outside as the light source is carried out from the optical fiber 51 for an input, and the liquid crystal optical equipment of an example 1 is introduced inside the liquid crystal optical element 30 from 1st prism object 2A of an input side through the input interface 55. 2nd prism object 2B, the output interface 56, and the optical fiber 52 for an output are mostly formed in the symmetry with the input side also at the output side.

[0017] What bundled the fiber of the numerical aperture (N.A.) 0.57 which uses multicomponent glass as a core as optical fibers 51 and 52 of the input side and output side which are used as a light guide means, and was used as the bundle fiber with a diameter of 5mm was used.

[0018] Parallel Guanghua of the light by which outgoing radiation was carried out from the bundle fiber 51 is carried out to the input interface 55 and the output interface 56 with a convex lens 55 using a convex lens, and parallel light is condensed on the outgoing radiation side bundle fiber 52 with the convex lens 56. Although the input interface 55, the output interface 56, the light guide means 51 and 52, prism object 2A, 2B, and the structure where 3 and 4 were joined are describing in drawing 1 -4, the light guide may be carried out through space as mentioned above.

[0019] In order to reduce firmer immobilization and interface reflected light loss, the structure which joined the input interface and the output interface to the light guide means and the prism object, respectively, using a refractive-index distribution pattern (gray TEDDO index) rod lens as an input interface and an output interface as shown in drawing 1 -4 is desirable. As for prism object 2A, 2B, and the liquid crystal optical element 30, it is desirable that a refractive index is a comparable optical material, and each is joined in optical adhesives with a comparable refractive index, or coupling oil.

[0020] When carrying out the light guide of the inside of a liquid crystal optical element using the total reflection in the front face of the front substrate 31 of the liquid crystal optical element 30, while a configuration is easy, about 100% of high reflection factor is obtained. However, critical angle thetac the incident angle within a front substrate (refractive index n) is described to be by the following (1) formula in order for total reflection to happen It must be more than (degree).

sin(thetac) =1/n (1)

[0021] Therefore, the include angle of prism object 2A, and the inclined plane of 2B and the front substrate of the liquid crystal optical element 30 to make must be carried out above (90 degree-thetac). When forming the reflective film in the front face of the front substrate 31 of the liquid crystal optical element 30, since there is no constraint like (1) type, its tolerance of formation of prism object 2A and 2B is on the other hand, wide.

[0022] The liquid crystal optical element 30 consists of the front substrate 31, transparent front electrode 30A, liquid crystal resin complex layer 30B, flesh-side electrode 30C that reflects light by non-transparence and makes a reflective means serve a double purpose, and a flesh-side substrate 32. The heat regulator is formed in the flesh-side substrate 32 side. Furthermore, it consists of a drive circuit which drives a liquid crystal optical element, ********** which carries out drive control of the heat regulator.

[0023] The case in this example, by repeating reflection between flesh-side electrode 30C combining and [front / 31] and a reflective means, using the interface of the glass and air of

the front substrate 31 of a liquid crystal optical element as a total reflection side, and passing a liquid crystal solidification object complex layer 4 times or more, scattering power can be improved further and an extinction ratio can be improved.

[0024] It is made for the total reflection in which the reflection by the interface of the vitreous front substrate 31 and air becomes settled with the refractive index of glass to happen like drawing 1 at this time. Or mirrors, such as metal mirrors, such as aluminum and silver, and a multilayer dielectric film, may be formed. As a normal reflective reduction means, the field of the front substrate 31 in which front electrode 30A is formed is made into the frosting side in which detailed irregularity was formed.

[0025] Next, it outlines about the configuration of the liquid crystal solidification object complex used by this invention. In the liquid crystal optical element in this invention, the liquid crystal display component which pinched the liquid crystal solidification object complex with which distributed maintenance of the nematic liquid crystal was carried out into the solidification object matrix is used. It is desirable to use the liquid crystal solidification object resin complex it was made mostly in agreement [complex] with the Tsunemitsu refractive index (no) of the liquid crystal which distributed maintenance of the nematic liquid crystal which has a forward dielectric anisotropy especially is carried out into a solidification object matrix, and the refractive index of the solidification object matrix uses. And liquid crystal solidification object complex is pinched between substrates with the electrode of a pair.

[0026] no of a nematic liquid crystal When the refractive-index anisotropy which is a difference with an extraordinary index (ne) is set to **n, as for **n, it is desirable that it is 0.18 or more. Moreover, in order to obtain scattering power with a high liquid crystal solidification object complex layer to the specific wavelength lambda (micrometer), it is desirable that the mean particle diameter R of liquid crystal (micrometer) has gathered according to the wavelength. In fact, it is desirable to fill the relation of ** n-R**lambda.

[0027] Therefore, when modulating the light of the wavelength band (lambda=0.4-0.7 (micrometer)) of the light using the bundle fiber for optical energy transmissions, in order for the scattering power in a liquid crystal solidification object complex layer to become homogeneity mostly in a full wave length region, it is desirable to be distributed over the range in which the mean particle diameter R of liquid crystal fills the relation of 0.4<**n-R<0.7.

[0028] When, using the light of the semiconductor laser diode of a non-light region, or the single wavelength of the near-infrared wavelength region (lambda=0.8-1.6 (micrometer)) of LED as a light on the other hand using the single track fiber for optical communication, or when using for optical measurement the light of the single wavelength of the helium-Ne laser which is the laser of a light oscillation, or semiconductor laser, the mean particle diameter R of liquid crystal has the desirable structure with little particle size distribution where ** n-R**lambda is filled.

[0029] As for the substrate with this electrode, that by which the electrode was prepared on substrates, such as glass, plastics, and a ceramic, is used. A transparent ingredient is used for the substrate by the side of plane of incidence at least in this invention. Glass is suitable for forming few still flatter and optical distorted substrate sides.

[0030] Between the substrates of a pair with an electrode, liquid crystal solidification object complex is pinched, respectively. Electric field occur by impression of an electrical potential difference, this liquid crystal solidification object complex changes the orientation of a liquid crystal molecule according to that electric field, and the refractive index of the liquid crystal in liquid crystal solidification object complex changes. When the refractive index of the solidification object matrix is mostly in agreement with the refractive index of liquid crystal, light penetrates, and light is scattered about when not in agreement. Since the liquid crystal optical element using this liquid crystal solidification object complex does not use the polarizing plate, an optical modulator with little optical loss is obtained.

[0031] The liquid crystal solidification object complex which specifically consists of a solidification object matrix by which a large number formation of the hole fine as a liquid crystal display component was carried out, and a nematic liquid crystal with which the part of the hole was filled up is used. This liquid crystal solidification object complex is pinched between electrode substrates. The refractive index of the liquid crystal changes and the relation between

the refractive index of a solidification object matrix and the refractive index of liquid crystal changes with the impression conditions of an electrical potential difference inter-electrode [the]. When these both refractive index is mostly in agreement, it will be in a transparency condition, and when refractive indexes differ, a liquid crystal optical element which will be in a dispersion condition can be used.
[0032] The liquid crystal solidification object complex which consists of a solidification object matrix by which a large number formation of this fine hole was carried out, and liquid crystal with which the part of that hole was filled up is the structure by which liquid crystal was confined in a liquid bubble like a microcapsule. However, each microcapsule does not need to be independent completely and the liquid bubble of each liquid crystal may be open for free passage through a slit like a porous body. Furthermore, the degree of a free passage may be high and in the condition which liquid crystal is opening for free passage in the shape of a stitch is sufficient.
[0033] The liquid crystal solidification object complex used for this invention is the following, and is made and manufactured. A nematic liquid crystal and the hardenability compound which constitutes a solidification object matrix are mixed, and it is made the shape of the shape of a solution, and a latex. Subsequently, what is necessary is for photo-curing, heat curing, hardening by solvent removal, reaction hardening, etc. to carry out this, to separate a solidification object matrix, and just to take the condition that the nematic liquid crystal distributed in the solidification object matrix.
[0034] Since the hardenability compound to be used can be hardened within a sealing system by making it photo-curing or a heat-curing type, it is desirable. When a photo-curing type hardenability compound is used especially, it cannot be influenced by heat, can be made to harden for a short time, and is desirable. After forming a cel using a sealant like the conventional usual nematic liquid crystal as a concrete process, pouring in non-hardened mixture [compound / a nematic liquid crystal and / hardenability] from an inlet and closing an inlet, it can heat whether an optical exposure is carried out and can also be made to harden.
[0035] Moreover, in the case of the liquid crystal optical element in this invention, non-hardened mixture [compound / a nematic liquid crystal and / hardenability] can be supplied on the substrate which prepared the transparent electrode as an electrode, not using a sealant, and another substrate with an electrode can also be stiffened by optical exposure etc. in piles after that. Of course, after that, a sealant may be applied on the outskirts and the seal of the circumference may be carried out. According to this process, in order for what is necessary to be just to only supply a roll coat, a spin coat, printing, spreading according non-hardened mixture [compound / a nematic liquid crystal and / hardenability] to a dispenser, etc., an impregnation process is simple and productivity is very good.
[0036] Moreover, into non-hardened mixture [compounds / these / nematic liquid crystals and hardenability compounds], spacers, such as a ceramic particle for substrate gap control, a plastics particle, and a glass fiber, a pigment, coloring matter, a viscosity controlling agent, and the other additives that do not have a bad influence on the engine performance of this invention may be added.
[0037] As mentioned above, although the manufacture approach by the photopolymerization method was shown, microencapsulation liquid crystal can also be formed also by the emulsion method.
[0038] Below, the other requirements for a configuration are explained. As front electrode 30A of the liquid crystal optical element 30, transparent electrodes, such as ITO, are formed on the vitreous front substrate 31 in which frosting processing was carried out by etching and polish with acid liquid. The irregularity formed of frosting processing should just be a configuration which reduces that normal reflection in the field finally reaches the light guide means 52 by the side of outgoing radiation.
[0039] Therefore, the irregularity of the shape of a rectangle in which many fields parallel to reflector 30C exist is unsuitable, and its irregularity of the shape of ** which is the aggregate of the slant face which has a tilt angle is desirable. Although this tilt angle is related to the incident angle to the effective diameter of the light guide means 51 and 52, the input interface 55, the output interface 56, and a liquid crystal solidification object complex layer, the count of

reflection, etc., generally as unnecessary interface reflection as the irregularity of the shape of sharp ** is removed, so that a tilt angle is perpendicularly near.
[0040] However, since surface area increases so that an acute angle, the rate of interface reflection increases and the transmitted light which can be used decreases. Therefore, the irregularity of the shape of ** with many inclination components which do not cause the remarkable decline in permeability but can reduce unnecessary interface reflection is desirable. Moreover, as a display device in this liquid crystal optical equipment, since the homogeneity of the property within a field is not required, the constraint about concavo-convex magnitude (pitch) is not so severe, but in the property of the amount of transmitted lights over applied voltage, when a sharper standup is needed like [in the case of an on-off control action], concavo-convex magnitude (pitch) is so desirable that it is small.
[0041] It is more desirable to make it into a big value, concavo-convex pitch, i.e., depth, and for the thickness of a liquid crystal solidification object complex layer to distribute on the other hand, since the property of the amount of transmitted lights over gently-sloping applied voltage is required for application of the dimmer which wants to control the middle quantity of light finely. in order to reduce further the interface reflectivity produced between the transparent electrodes and liquid crystal solidification object complex layers which were formed on the concave convex — a transparent electrode layer top — SiO2 MgF2 etc. — it is desirable to form a low refractive-index layer as an antireflection film. Moreover, the vitreous flesh-side substrate 32 which formed the aluminum film to serve also as an electrode as reflector 30C was used. It is good also as structure which carried out the laminating of the transparent electrode on the derivative multilayers mirror in addition to the metal membrane.
[0042] When using the total reflection produced in the interface of the reflector of the front substrate 31, and air, since a surface foreign matter and dirt become the cause of degrading total reflection effectiveness, it is desirable to form in a front face the film with a small refractive index, for example, the polymer which has a fluorine-containing aliphatic series ring structure, (trademark: SAITOPPU) as a protective coat from a front substrate ingredient.
[0043] Furthermore, when a liquid crystal solidification object complex layer is in a transparence condition, the reflector field where total reflection of the light is carried out with the front substrate 31 is only a part as shown in drawing 1 , but when a liquid crystal solidification object complex layer is in a dispersion condition, incidence of the scattered light is carried out to the larger range of an interface with the air of the front substrate 31. In order to remove such the unnecessary scattered light efficiently, it is effective to form light absorption objects, such as a black coating, in addition to the total reflection field needed.
[0044] Moreover, the heat sink by which the temperature sensor and the electrical heater were built in the background of the reflector of a liquid crystal optical element was pasted up. Furthermore, the fan for air cooling was attached behind this heat sink, and it could be made to carry out by the electrical heater and the fan for air cooling the temperature control, acting as the monitor of the temperature so that a liquid crystal optical element may be maintained by laying temperature.
[0045] The light guide of the sources of the light, such as a halogen lamp, Xe lamp, and a metal halide lamp, was carried out to the incidence side optical fiber 51, and it considered as incident light. Alternating voltage was impressed to inter-electrode [of the aforementioned liquid crystal optical element 30] for the 100Hz square wave, and it considered as the dimmer by modulating an effective voltage value by the external circuit, and changing the transparency dispersion condition of a liquid crystal optical element. The optical property was measured using the liquid crystal optical equipment using the liquid crystal optical display device of the optical fiber of this invention produced with such a configuration, and a transparency dispersion mold. The result was summarized in Table 1.
[0046] In Table 1, relative light transmittance makes the example of a comparison 100%. moreover, measurement — constant temperature — carried out within a degree tub, temperature means not the temperature of a liquid crystal display component but the ambient temperature of optical equipment, and a measurement extinction ratio shows the range of the light value ratio of the outgoing radiation side fiber 52 to the applied-voltage values 0V and 30V

of the liquid crystal optical element in a 0 to 50 degrees C temperature requirement. Same optical property evaluation was performed about the thing of a configuration of having made the table electrode 30A page into the flat side among the liquid crystal optical elements of a configuration of having been shown in the example 1 as an example of a comparison, and the result was indicated.

[0047]

[Table 1]

	不要な正規反射光除去手段	相対的光透過率	消光比	応答速度（ｍｓｅｃ）
実施例１	フロスト面あり	９８％	２５０～２８０	１５
比較例１	フロスト面なし	１００％	３～　１５	１５～２００

[0048] This result shows that the improvement in fast of an extinction ratio and stability are attained by the configuration of this invention while optical loss has been almost small. Therefore, adjustment of the outgoing radiation quantity of light corresponding to an applied-voltage value can carry out to a high speed arbitrarily [there is little quantity of light loss and] by using this optical equipment as a dimmer.

[0049] Moreover, the optical outgoing radiation edge of an outgoing radiation side optical fiber is turned to an illuminated object, and this liquid crystal optical equipment installs it, and when carrying out optical high measurement of a S/N ratio by the lock-in amplifier, it can use the electrical signal of photodetectors, such as the photomultiplier tube and Si photodiode, as a required fiber type light chopper. Compared with a conventional pivoted window type chopper or a conventional oscillatory type chopper, small and high-speed optical chopping becomes possible.

[0050] Metallic reflection mirrors, such as aluminum, are sufficient as reflector 30C, and an optical interference multilayers reflecting mirror is sufficient as it. In the case of the former, in order that a reflector may serve also as an electrode, manufacture is easy, and a component can be constituted without complicating structure. In the case of the latter, it is also possible to form the cold mirror which has the spectral characteristic which penetrates a heat ray and reflects only the light by the configuration of multilayers, and it has the degree of freedom which can also form the mirror of 100% of reflection factors to the specific semiconductor laser wavelength used by optical communication.

[0051] (Example 2) It explains using drawing 2 . In this example, unlike the configuration of an example 1, each of front electrode 30A and flesh-side electrode 30C is transparent electrodes, and it is a flat side mostly [both]. Moreover, by opening enough the distance d of liquid crystal solidification object complex layer 30B and the reflector of a reflective means The optical path of the normal reflected light which produces the optical path of the normal reflected light produced in an interface with the field of liquid crystal solidification object complex layer 30B of thickness t, transparent front electrode 30A, and flesh-side electrode 30B in the field of a liquid crystal optical element is shifted to the field inboard of a liquid crystal optical element. The unnecessary interface reflected light can be prevented from reaching the light guide means 52 by the side of outgoing radiation.

[0052] This shift-amount delta is described to be delta=2d-tantheta by the distance d of the incident angle theta of the incident light to liquid crystal solidification object complex layer 30B, and the reflector of a reflective means. In order not to make the unnecessary interface reflected light reach the outgoing radiation side light guide means 52, shift-amount delta should just be more than the exposure width of face L of the incident light to liquid crystal solidification object complex layer 30B. Thus, if shift-amount delta required to remove the unnecessary interface reflected light becomes settled, spacing d can be found according to it. Since a liquid crystal optical element will be enlarged if thickness d more than fixed is needed when the function as a

substrate of one side holding a liquid crystal solidification object complex layer is also taken into consideration, and d is made into a big value on the other hand, about d= 0.5-30mm is desirable in fact.

[0053] Moreover, in this example, the refractive-index distribution pattern (gray TEDDO index) rod lens was used as the input interface 55 and an output interface 56, using quartz system single-mode optical fiber with a core diameter [for optical-communication information transmissions] of 10 micrometers as light guide means 51 and 52. Optical fiber guided wave light used the semiconductor laser light of the wavelength of 1.3 micrometers, and 1.5-micrometer near-infrared region. Prism object 2A and 2B are joined to the front substrate 31 of the input interface 55, the output interface 56, and the liquid crystal optical element 30 with optical adhesives, as respectively shown in drawing 2 .

[0054] Moreover, the dielectric multilayer reflecting mirror which reflects the light of the wavelength band of guided wave light only in the reflector part of the front face of the front substrate 31 of the liquid crystal optical element 30 99% or more is formed, and the light absorption object is applied to the front face of other front substrates 31. In order to perform reflection in the front face of the front substrate 31 not by total reflection but by the dielectric multilayer reflecting mirror, it is not necessary to fill with this example the total reflection conditions described by (1) formula.

[0055] Therefore, in order to prevent carrying out total reflection of the guided wave light with unnecessary scattered light in liquid crystal solidification object complex layer 30B, wavelength light other than guided wave light, etc. on the front face of the front substrate 31, and a part guiding waves (1) Critical angle thetac which becomes settled by the formula It determined that the tilt angle of prism object 2A and 2B carried out incidence to liquid crystal solidification object complex layer 30B by the small incident angle, and the rate that an unnecessary light guides the liquid crystal optical element 30 interior was reduced.

[0056] In this example, it considered as the thickness of about 20 micrometers of liquid crystal solidification object complex layer 30B, and boro-silicated glass of about 1mm of board thickness was used for the front substrate 31 and the flesh-side substrate 32. Consequently, the high extinction ratio of 106 more than and the speed of response of 2 or less msecs were stabilized, and were obtained.

[0057] (Example 3) It explains using drawing 3 . Unlike the configuration of an example 1, in this example, both the field of front electrode 30A and the field of flesh-side electrode 30C are almost flat. Light is reflected by the light reflex means 90 of the dedication prepared in the rear-face side of the flesh-side substrate 32. Moreover, unnecessary interface reflection of the liquid crystal optical element 30 interior is removable by not supposing that transparent front electrode 30A and flesh-side electrode 30C which touch liquid crystal solidification object complex layer 30B are parallel to the light reflex means 90, but attaching whenever [suitable tilt-angle].

[0058] Since the flat profile irregularity of a substrate is not required so much in the case of this invention which is made to transmit due to about 1 to 1, without converging light, it is satisfactory even if it uses a long film formation technique using a cheap film-like substrate with sheet metal like a PET film.

[0059] In this example, it is arranged so that the unnecessary normal reflected light of the interface in the liquid crystal solidification object complex layer 30B may carry out incidence to the outgoing radiation side optical fiber 52, and may not cause degradation of an extinction ratio, and front electrode 30A, liquid crystal solidification object complex layer 30B, the field side of flesh-side electrode 30C, and the reflector 90 of a light reflex means may incline.

[0060] The tilt angle alpha will not carry out incidence of the unnecessary reflected light produced in the interface of a liquid crystal solidification object complex layer to the light guide means 52, if it is set as the liquid crystal solidification object complex layer which becomes settled with the effective diameter of the light guide means 51 and 52, and the focal distance of close and the output interfaces 55 and 56 to the distributed angle theta of the parallel light which carries out incidence more than theta.

[0061] Since N.A. is also small, the range of alpha of 0.1 degrees - 10 degrees is [whenever /

tilt-angle] desirable [a core diameter is as thin as 200 micrometers or less, and] in the case of the single track fiber for optical communication. Since it uses as a bundle fiber etc. in the case of the fiber for optical energy transmissions, and the diameter of a fiber of the optical transmission section is as thick as about 2-20mm, the range of alpha of 1 degree - 20 degrees is [whenever / tilt-angle] on the other hand, desirable.
[0062] Furthermore, although the interface reflected light is removed also when it considers as whenever [big tilt-angle / alpha], the light which carries out incidence from across becomes most at a liquid crystal solidification object complex layer, and effectual permeability falls that it is easy to produce Hayes accompanying index mismatching at the time of transparence. Moreover, since a liquid crystal optical element will become thick and the magnitude and weight of the whole equipment will increase if alpha becomes large whenever [tilt-angle], limiting to the above-mentioned range is [whenever / tilt-angle] desirable [alpha].
[0063] Since the bundle fiber with a same effective diameter [as an example 1] of 5mm and the convex lens with a focal distance of 30mm were used, the distributed angle theta of the parallel light which carries out incidence to a liquid crystal solidification object complex layer became about 10.6 degrees, and made 12 degrees of liquid crystal solidification object complex layers incline to the reflector of a light reflex means in this example.
[0064] In this example, in order to perform a temperature control to accuracy more and to secure the repeatability of an optical property also to large environmental temperature, the reflecting mirror was used as the cold mirror and the heat sink where the Peltier device and temperature sensor of electronics control were embedded as a heat regulator 60 was used.
[0065] When the configuration of drawing 3 estimated the optical property, while the extinction ratio 320 was always obtained from -20 degrees C in the large environmental temperature of 80 degrees C, the result of having been stabilized by the applied-voltage pair optical output property to the temperature change was obtained. Moreover, compared with the thing of aluminum nature, since the reflection factor was high about 10%, as for relative light transmittance, the direction of cold mirror nature became a high value compared with the example 1 of a comparison.
[0066] Furthermore, in the liquid crystal optical equipment of the configuration of an example explained above, it has composition which may be able to carry out forcible temperature control of the liquid crystal optical element 30 from a reflector side (background of the flesh-side substrate 32). As a compulsive temperature control method, it equips with a heat sink and cools with an air cooling fan. Or it can equip with a Peltier device, an electrical heater, and a temperature sensor, and temperature control can also be depended and carried out to heating and cooling so that it may be maintained by fixed temperature.
[0067] (Example 4) The example 4 of this invention is explained using drawing 4 . In this example, it consists of a liquid crystal optical element 30 of the incidence side optical fiber 51 and the outgoing radiation side optical fiber 52, the prism object 3 equipped with the total reflection side of a V type, and the reflective mold that functions as the light modulation section, and a heat regulator 60 using the single track optical fiber for optical communication, and consists of an electronic circuitry which carries out drive control of the drive circuit and heat regulator 60 which drive a liquid crystal optical element further.
[0068] Moreover, it consisted of the 1st interface 55 or 2nd interface 56 etc. which serves as the liquid crystal optical element 30 and the prism object 3 from a rod lens, and each optical element is pasted up on one with optical adhesives.
[0069] Frosting processing of the glass side of a substrate 31 in which transparent front electrode 30A (ITO etc.) by the side of the optical plane of incidence of the liquid crystal optical element 30 or an outgoing radiation side is formed is carried out. On the flesh-side substrate 32 with which the optical interference multilayers mirror which reflects the luminescence wavelength of specific LD (laser diode) or LED which is incident light as a reflector was formed, the transparent electrode was formed and the opposite substrate was formed. As an optical fiber by the side of the incidence of a liquid crystal optical element, and outgoing radiation, it is the quartz system fiber of FC connector connection mold, and the step mold refractive-index distribution optical fiber for multi-mode transmission with a core diameter of 50 micrometers

was used.
[0070] As an input interface and an output interface, the rod lens (NSG: SELFOC lens) of diameter =1.8mm, pitch =1/4, and the gray TEDDO index mold for wavelength 830nmLD of lens length =4.73mm was used for each.
[0071] After reflecting an almost parallel light by which outgoing radiation was carried out from the input interface 55 (rod lens) by one prism total reflection side 3a, using BK7 of optical glass as a prism object, incidence is carried out to the liquid crystal optical element 30 of a reflective mold by about 18-degree incident angle. After reflecting the normal reflected light reflected with the reflective means (flesh-side electrode 30C is made to serve a double purpose) by another prism total reflection side 3b, the light guide is carried out with an output interface. It is further condensed by the end face of the optical fiber 52 by the side of outgoing radiation, and this light turns into outgoing radiation light.
[0072] In this example, the always stabilized optical property was obtained in large environmental temperature like the example 2 using the heat sink where the Peltier device and temperature sensor of electronics control were embedded as a heat regulator 60. The result of having measured the optical property was summarized in Table 2 using the optical fiber of this invention and the **** liquid crystal optical equipment for transparency dispersion mold display devices which were produced with such a configuration. In Table 2, relative light transmittance makes the example of a comparison 100%.
[0073] moreover, measurement -- constant temperature -- carried out within the degree tub, temperature meant not the temperature of a liquid crystal display component but the ambient temperature of optical equipment, and evaluated the measurement extinction ratio and the speed of response to the applied-voltage values 0V and 100V of a liquid crystal optical element in the -20 to 60 degrees C temperature requirement.
[0074] As an example of a comparison, the flat side of the ITO electrode surface by the side of the optical incidence of the liquid crystal optical element which is a configuration conventionally was carried out, and the same optical property evaluation result was indicated also about the thing of a configuration of not carrying a heat regulator 60.
[0075]
[Table 2]

	不要な正規反射光除去手段	相対的光透過率	消光比	応答速度（ｍｓｅｃ）
実施例３	傾斜角度	９９％	３００００	１．５
比較例２	な　し	１００％	５～２５	１．５～１００

[0076] From this result, the configuration of this invention shows that the improvement in fast of an extinction ratio and stability are attained, while there has almost been no optical loss. Therefore, by using this optical equipment as a good light variation attenuator for optical communication, there is little quantity of light loss and adjustment of the outgoing radiation quantity of light corresponding to an applied-voltage value can carry out to a high speed arbitrarily.
[0077] Other configurations may be used although the configuration using the prism object 3 which has the total reflection side of a V type described in this example. For example, an optical path may be bent according to the spherical surface or the aspheric surface. Moreover, an extinction ratio is also further improvable by considering as the configuration which changed the ratio of the configuration of the total reflection side of the prism object 3, and the core diameter of an optical fiber.
[0078] (Example 5) An example 5 is explained using drawing 5 . In this example, by carrying out incidence of the optical fiber for an input, and the almost parallel light by which outgoing radiation was carried out to the prism object 4 from the interface 55 (rod lens) for an input with

the prism object 4 of a trapezoid configuration by the suitable incident angle for the liquid crystal optical element 30 of a reflective mold, total reflection is carried out by flesh-side electrode 30C, and total reflection is again carried out by top total reflection side 4a of the prism object 4. And if the prism object 4 is arranged in a suitable location, reflection will be rewound two or more times in respect of the reflector of a liquid crystal optical element, and total reflection, and light will be outputted to the interface 56 for an output by the side of outgoing radiation the back the bottom.

[0079] With such a configuration, an extinction ratio can be further raised compared with the configuration in the conventional example which passes light only twice by passing a liquid crystal solidification object complex layer 4 times or more. Although drawing 5 is describing the case where a liquid crystal solidification object complex layer is passed 4 times, the count of passage is changeable into arbitration by the multiple of 2 by changing suitably the die length (the die length of the longitudinal direction of top-face 4a) and the incident angle of the prism object 4.

[0080] The same configuration as an example 1 is sufficient as the liquid crystal optical element 30 of a reflective mold, and it may not form a reflector in contact with liquid crystal solidification object complex layer 30B like an example 2 or an example 3, but may establish the light reflex means by the external reflector. In this case, what is necessary is for what both sides of a front electrode and a flesh-side electrode are made into a frosting side, you prepare spacing with the reflector of a light reflex means in a liquid crystal solidification object complex layer like an example 2 as a normal reflective reduction means, or is made for the reflector of a light reflex means and liquid crystal solidification object complex layer 30B to incline suitably like an example 3 (refer to drawing 3) just to remove interface reflection with liquid crystal solidification object complex layer 30B and an electrode surface.

[0081] About 2-200 micrometers is desirable, and concavo-convex magnitude (pitch) is concavo-convex depth (ten-point average depth) RZ. About 0.1-10 micrometers is desirable. Moreover, when light carries out incidence from across to a liquid crystal solidification object complex layer in this way, it is desirable that index matching with the liquid crystal at the time of transparence makes it whenever [optical incident angle] most at the optimal (as [decrease / namely, / Hayes]) combination.

[0082] As mentioned above, although the example was explained, an approximate account is performed about the magnitude of each part etc. next. In transmitting light energy, a halogen lamp, a metal halide lamp, Xe lamp, etc. are used as the light source, and in order for all to condense efficiently using a condensing means and for luminescence length to do a light guide to a fiber about 2-10mm for a certain reason, the fiber diameter of about 3-10mm is needed.

[0083] Moreover, the magnitude of the light source has the width of face of 10-30cm (500W-3kW) extent from die length of 3-10cm (10W - 500W class), and the magnitude of a converging mirror will also be doubled according to the classification of the light source. And although the magnitude of a liquid crystal optical element is decided according to N.A. of the magnitude, for example, the focal distance and effective diameter, and the fibers of the condensing means to be used (an ellipse mirror, lens, etc.) etc., when using the above-mentioned light source, it is about considered about 1-30cm of vertical angles.

[0084] In using for the purposes, such as a communication link and optical measurement, the incidence aperture of light is 1mm or less, and the diameter is set to 1cm or less even if it uses a lens, since the emission light of laser die auto or LED is condensed. Since the optical transmission section core diameter of the single track fiber for optical communication is 200-micrometer or less extent, the magnitude of a liquid crystal optical element is set to about about 1-5cm.

[0085]

[Effect of the Invention] In order to make the light modulation part of a liquid crystal optical element carry out multiple-times passage of the light by which outgoing radiation was carried out from the light source with the liquid crystal optical element which can control a dispersion condition and a transparency condition electrically, and the light reflex means according to this invention like the above, compared with the case where it penetrates only once, effectual

scattering power improves by leaps and bounds.
[0086] Moreover, form irregularity in the interface of a liquid crystal solidification object complex layer and a transparent electrode as a normal reflected light reduction means. Or or it makes spacing d of the liquid crystal solidification object complex layer of a liquid crystal optical element, and a light reflex means into 10 or more times to thickness t of a liquid crystal solidification object complex layer, do not make parallel a liquid crystal solidification object complex layer and a reflector, but attach an inclination. Furthermore, the interface reflected light which is the main factor of background noise is reduced by applying the charge of black-colored to the interface reflector part which carries out incidence to a direct optical fiber without passing a liquid crystal solidification object complex layer in a component interface with air.
[0087] Consequently, improvement in the extinction ratio in the good modulation light function according to applied voltage and its dynamic range was attained. Moreover, since a thermoregulator was constitutionally installed in one side of a liquid crystal optical element, compulsory temperature control can maintain now at the temperature by which the optimal characteristics of a liquid crystal optical element are always discovered regardless of perimeter environmental temperature, and the stable modulated light and the stable optical shutter ring were realized.
[0088] As a concrete example, there is stroboscope lighting as the light source for lighting which has a high-speed shutter function. That is, high-speed photography is attained. For example, if the body which moves at the rate of 360 km/s is irradiated when shutter speed is 1ms, a 1cm moving-average image will be recorded.
[0089] Moreover, if shutter ring lighting is carried out continuously and a high-speed migration body is photoed, a locus will be recorded in the shape of a step. Adjustable [of the shutter timing] can be carried out to arbitration, it uses as the light source for measurement turned on and off a fixed period as an example using the programmable special feature that high-speed flattery nature is, and high measurement of a S/N ratio is attained also in an environment with much a feeble signal light or noise light by amplifying and detecting only the signal light of the period.
[0090] Moreover, without light passing through the inside of air in this invention, since only the solid-state medium by which it was altogether cheated out of the refractive index optically closely is passed, loss becomes small.
[0091] Consequently, this optical equipment can be used now for optical measurement as a lighting system with a modulated light function, or a lighting system with an optical shutter ring function. The S/N ratio has been improved by taking photodetection equipment and a synchronization like the light chopper for lock in amplifier, and performing a shutter ring especially. Moreover, also in the optical-communication field, the optical attenuator of a fixed attenuation factor used conventionally can obtain now the strange optical attenuator which can be decreased by applied-voltage adjustment.

[Translation done.]

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TECHNICAL FIELD

[Industrial Application] This invention relates to the liquid crystal optical equipment using the liquid crystal optical element of the transparency dispersion mold equipped with an optical fiber and liquid crystal solidification object complex, and the lighting system using it.

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PRIOR ART

[Description of the Prior Art] A liquid crystal optical element is arranged between the light source and the optical fiber for optical transmissions from the former, and the liquid crystal optical equipment which controls the quantity of light transmitted to an optical fiber from the light source by the liquid crystal optical element is known. Furthermore, the lighting system and luminous-intensity-distribution equipment using the optical fiber bundle, the light source, and the liquid crystal optical element which bundled the optical fiber for optical energy transmissions or the optical fiber of single track are proposed.
[0003] Moreover, an optical fiber is used for the light guide means from the light source to a liquid crystal optical element, and the configuration which has arranged the liquid crystal optical element between optical fibers is proposed. The basic arrangement is shown in drawing 6 as a conventional example. It consists of liquid crystal optical elements 30 which show the mode of operation of the transparency dispersion mold equipped with the optical fiber 51 for incidence, the optical fiber 52 for outgoing radiation, a convex lens 41, and a reflective mold means and liquid crystal solidification object complex. And this configuration can attain the modulation of light.
[0004] Moreover, although it is the arrangement configuration which resembled this conventional example, the optical variable attenuator which used the low loss thin line optical fiber for optical-communication information transmissions for the optical optical incidence [of a liquid crystal optical element] and outgoing radiation side is proposed. As mentioned above, since reduction of optical loss is attained by using the liquid crystal optical element equipped with the liquid crystal solidification object complex which has the mode of operation of a transparency dispersion mold, and can control light without a polarizing plate, even if it uses a high-reflective-liquid-crystal optical element and a lens, it is proposed that optical variable attenuator can be built.

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EFFECT OF THE INVENTION

[Effect of the Invention] In order to make the light modulation part of a liquid crystal optical element carry out multiple-times passage of the light by which outgoing radiation was carried out from the light source with the liquid crystal optical element which can control a dispersion condition and a transparency condition electrically, and the light reflex means according to this invention like the above, compared with the case where it penetrates only once, effectual scattering power improves by leaps and bounds.
[0086] As an example, a tetramethoxy silane, a tetra-ethoxy silane, tetra-butoxysilane, A tetra-phenoxy silane, methyl trimetoxysilane, ethyl trimethoxysilane, Butyltrimethoxysilane, isobutyl trimethoxysilane, tert-butyltrimethoxysilane, Isopropyl trimethoxy silane, cyclohexyl tri-metoxy silane, Phenyl trimethoxysilane, vinyltrimetoxysilane, dimethyl dimethoxysilane, Diethyl dimethoxysilane, dipropyl dimethoxysilane, propylmethyl dimethoxysilane, Diisopropyl dimethoxysilane, dibutyl dimethoxysilane, diisobutyl dimethoxysilane, G tert-butyl dimethoxysilane, butyl methyl dimethoxysilane, Butyl ethyl dimethoxysilane, tert-butyl methyl dimethoxysilane, Isobutyl isopropyl dimethoxysilane, tert-butyl isopropyl dimethoxysilane, Hexyl methyl dimethoxysilane, hexyl ethyl dimethoxysilane, Dodecyl methyl dimethoxysilane, dicyclopenthyl dimetoxysilane, Cyclopentyl methyl dimethoxysilane, cyclopentyl ethyl dimethoxysilane, Cyclopentyl isopropyl dimethoxysilane, cyclopentyl isobutyl dimethoxysilane, Cyclopentyl-tert-butyl dimethoxysilane, dicyclohexyl dimetoxysilane, Cyclohexyl methyldimetoxysilane, cyclohexyl ethyl dimethoxysilane, Cyclohexyl isopropyl dimethoxysilane, cyclohexyl isobutyl dimethoxysilane, Cyclohexyl-tert-butyl dimethoxysilane, cyclohexyl cyclopentyl dimethoxysilane, Cyclohexyl phenyl dimethoxysilane, diphenyl dimethoxysilane, Phenylmethyl dimethoxysilane, phenyl isopropyl dimethoxysilane, Phenyl isobutyl dimethoxysilane, phenyl-tert-butyl dimethoxysilane, Phenyl cyclopentyl dimethoxysilane, vinyl methyl dimethoxysilane, Methyl triethoxysilane, ethyltriethoxysilane, epoxybutyltriethoxysilane, Isobutyl triethoxysilane, tert-epoxybutyltriethoxysilane, Isopropyl triethoxy silane, cyclohexyl ethoxy silane, Phenyl triethoxysilane, vinyltriethoxysilane, dimethyl diethoxysilane, Diethyl diethoxysilane, dipropyl diethoxysilane, propylmethyl diethoxysilane, Diisopropyl diethoxysilane, dibutyl diethoxysilane, diisobutyl diethoxysilane, G tert-butyl diethoxysilane, butyl methyldiethoxysilane, Butyl ethyldiethoxysilane, tert-butyl methyldiethoxysilane, Hexyl methyldiethoxysilane, hexyl ethyldiethoxysilane, Dodecyl methyldiethoxysilane, dicyclopenthyl diethoxysilane, As dicyclohexyl diethoxysilane, cyclohexyl methyldietoxysilane, cyclohexyl ethyldiethoxysilane, diphenyl diethoxysilane, and a normal reflected light reduction means Form irregularity in the interface of a liquid crystal solidification object complex layer and a transparent electrode. Or or it makes spacing d of the liquid crystal solidification object complex layer of a liquid crystal optical element, and a light reflex means into 10 or more times to thickness t of a liquid crystal solidification object complex layer, do not make parallel a liquid crystal solidification object complex layer and a reflector, but attach an inclination. Furthermore, the thing for which the charge of black-colored is applied to the interface reflector part which carries out incidence to a direct optical fiber without passing a liquid crystal solidification object complex layer in a component interface with air The interface reflected light which is the main factor of background noise is reduced.

[0087] Consequently, improvement in the extinction ratio in the good modulation light function according to applied voltage and its dynamic range was attained. Moreover, since a thermoregulator was constitutionally installed in one side of a liquid crystal optical element, compulsory temperature control can maintain now at the temperature by which the optimal characteristics of a liquid crystal optical element are always discovered regardless of perimeter environmental temperature, and the stable modulated light and the stable optical shutter ring were realized.
[0088] As a concrete example, there is stroboscope lighting as the light source for lighting which has a high-speed shutter function. That is, high-speed photography is attained. For example, if the body which moves at the rate of 360 km/s is irradiated when shutter speed is 1ms, a 1cm moving-average image will be recorded.
[0089] Moreover, if shutter ring lighting is carried out continuously and a high-speed migration body is photoed, a locus will be recorded in the shape of a step. Adjustable [of the shutter timing] can be carried out to arbitration, it uses as the light source for measurement turned on and off a fixed period as an example using the programmable special feature that high-speed flattery nature is, and high measurement of a S/N ratio is attained also in an environment with much a feeble signal light or noise light by amplifying and detecting only the signal light of the period.
[0090] Moreover, without light passing through the inside of air in this invention, since only the solid-state medium by which it was altogether cheated out of the refractive index optically closely is passed, loss becomes small.
[0091] Consequently, this optical equipment can be used now for optical measurement as a lighting system with a modulated light function, or a lighting system with an optical shutter ring function. The S/N ratio has been improved by taking photodetection equipment and a synchronization like the light chopper for lock in amplifier, and performing a shutter ring especially. Moreover, also in the optical-communication field, the optical attenuator of a fixed attenuation factor used conventionally can obtain now the strange optical attenuator which can be decreased by applied-voltage adjustment.

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TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] In this case, in order that light may pass a liquid crystal solidification object complex layer twice by considering as the configuration of a reflective mold, the scattering power of the liquid crystal solidification object complex itself improves by leaps and bounds compared with the configuration of the transparency mold which light passes once.
[0006] However, in order for a part of interface reflection produced in the interface of a liquid crystal optical element, the interface of the lens for condensing, etc. to always carry out incidence to the optical fiber by the side of optical outgoing radiation, when liquid crystal solidification object complex was in a dispersion condition, the outgoing radiation quantity of light from an optical fiber did not become low, and the extinction ratio of the outgoing radiation light by the electrical-potential-difference impression to a liquid crystal solidification object complex layer and un-impressing was not able to say that it was high compared with the configuration of a transparency mold.
[0007] Therefore, the dynamic range of the quantity of light change accompanying the electrical-potential-difference seal of approval of a liquid crystal optical element hardly improved as compared with the component configuration of a transparency mold, and it was still a low characteristic value. Moreover, when the light source which emits a lot of light was used, the temperature rise of the liquid crystal optical element accompanying the radiant heat etc. was remarkable, the repeatability of various kinds of electro-optics properties (the property of applied-voltage pair light transmittance, a dynamic response characteristic, extinction ratio, etc.) became low, and exact modulated light became difficult.

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MEANS

[Means for Solving the Problem] The liquid crystal optical element characterized by this invention possessing the following, and a light reflex means, The second prism object and the second light guide means are established, and a light reflex means is arranged in the middle of the optical path from the light source to the second light guide means. [whether a liquid crystal solidification object complex layer approaches the reflector side of a light reflex means, and is arranged, and] Or stick to a reflector and are arranged, and the light by which outgoing radiation was carried out from the light source passes the first light guide means, and it carries out incidence inside a liquid crystal optical element from the incidence section of the first field of a liquid crystal optical element through the first prism object. It is reflected once or more with the first reflective section or light reflex means of a field, respectively, and outgoing radiation is carried out to the last from the outgoing radiation section of the first field. Furthermore, incidence is carried out to the second light guide means through the second prism object. By the time it results [from the incidence section] in the outgoing radiation section, it is 2n about a liquid crystal solidification object complex layer. Time (n= 1 or more integers) passage is carried out. [whether irregularity is prepared in at least one interface in the interface which the quantity of light is controlled by the transmittance of the light of a liquid crystal solidification object complex layer in this case, and crosses the optical path inside a liquid crystal optical element, and] Or the spacing d of the liquid crystal solidification object complex layer of a liquid crystal optical element, and a light reflex means [whether it considers as 10 or more times to thickness t of a liquid crystal solidification object complex layer, and] Or liquid crystal optical equipment characterized by making at least one interface in the interface which crosses the optical path inside a liquid crystal optical element incline only at the predetermined include angle alpha to the reflector of a light reflex means (1). Light source The first light guide means The first prism object The liquid crystal solidification object complex with which distributed maintenance of the liquid crystal was carried out into the solidification object matrix between the front substrate with which the front electrode was formed, and the flesh-side substrate with which the flesh-side electrode was formed is pinched. The liquid crystal solidification object complex layer which light penetrates when liquid crystal was controlled by the electric field generated between two electrodes, light is scattered about when the refractive index of liquid crystal is not in agreement with the refractive index of a solidification object matrix, and the refractive index of liquid crystal is mostly in agreement with the refractive index of a solidification object matrix
[0009] Moreover, between the light source, the first light guide means, the front substrate with which the front electrode was formed, and the flesh-side substrate with which the flesh-side electrode was formed The liquid crystal solidification object complex with which distributed maintenance of the liquid crystal was carried out into the solidification object matrix is pinched. Light is scattered about, in case liquid crystal is controlled by the electric field generated between two electrodes and the refractive index of liquid crystal is not in agreement with the refractive index of a solidification object matrix. The liquid crystal optical element equipped with the liquid crystal solidification object complex layer which light penetrates when the refractive index of liquid crystal was mostly in agreement with the refractive index of a solidification object matrix, A light reflex means, the second light guide means, and the prism object equipped with

the reflector are established. A light reflex means is arranged in the middle of the optical path from the light source to the second light guide means. [whether a liquid crystal solidification object complex layer approaches the reflector side of a light reflex means, and is arranged, and] Or stick to a reflector, it is arranged and the light by which outgoing radiation was carried out from the light source is made to pass the first light guide means. A light guide is carried out inside a prism object from the plane of incidence of a prism object, and incidence is further carried out inside a liquid crystal optical element from the incidence section of the first field of a liquid crystal optical element. It is reflected once or more with the reflector or light reflex means of a prism object, respectively. By the time it finally carries out incidence to the second light guide means from the outgoing radiation side of a prism object and reaches [from the plane of incidence of a prism object] the outgoing radiation side of a prism object, it is 2n about a liquid crystal solidification object complex layer. Time (n= 1 or more integers) passage is carried out. [whether irregularity is prepared in at least one interface in the interface which the quantity of light is controlled by the transmittance of the light of a liquid crystal solidification object complex layer in this case, and crosses the optical path inside a liquid crystal optical element, and] Or the spacing d of the liquid crystal solidification object complex layer of a liquid crystal optical element, and a light reflex means [whether it considers as 10 or more times to thickness t of a liquid crystal solidification object complex layer, and] Or the liquid crystal optical equipment (2) characterized by making at least one interface in the interface which crosses the optical path inside a liquid crystal optical element incline only at the predetermined include angle alpha to the medial axis of an optical path is offered.

[0010] Moreover, in the liquid crystal optical equipment with which irregularity was prepared in the interface of above liquid crystal optical equipment (1) or (2), the liquid crystal optical equipment (3) characterized by forming irregularity in the interface which a front electrode makes is offered. Moreover, in the liquid crystal optical equipment with which irregularity was prepared in any one interface of above liquid crystal optical equipment (1) − (3), the liquid crystal optical equipment (4) characterized by forming irregularity in the interface which a flesh-side electrode makes is offered.

[0011] Moreover, in the liquid crystal optical equipment with which irregularity was prepared in any one interface of above liquid crystal optical equipment (1) − (3), the liquid crystal optical equipment (5) characterized by coming to use a light reflex means also [electrode / almost flat / of a liquid crystal optical element / flesh-side] is offered. Moreover, in any one liquid crystal optical equipment of above liquid crystal optical equipment (1) − (5), the liquid crystal optical equipment (6) characterized by forming a heat regulator in a flesh-side substrate side further is offered. Furthermore, the lighting system equipped with any one liquid crystal optical equipment of above liquid crystal optical equipment (1) − (6) is offered.

[0012] In the liquid crystal optical equipment of this invention, detailed irregularity is formed in the transparent electrode side of a liquid crystal optical element as an unnecessary normal reflected light reduction means, or spacing d of the liquid crystal solidification object complex layer of a liquid crystal optical element and a light reflex means is made into 10 or more times to thickness t of a liquid crystal solidification object complex layer. Whenever [tilt-angle] is prepared for the liquid crystal solidification object complex layer of a liquid crystal optical element to the reflector of a light reflex means. The component which carries out incidence to the second light guide means among the normal reflection produced with these unnecessary reflective reduction means in the interface of a liquid crystal solidification object complex layer and substrate glass with a transparent electrode etc. is reduced.

[0013] Moreover, one-structure is adopted and a compact and the liquid crystal optical equipment which was optically [firmly and] excellent mechanically are offered so that the normal reflected light by the interface between a prism object and a liquid crystal optical element may be controlled positively.

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OPERATION

[Function] In order that according to this invention light may pass only through the inside of a solid-state medium and may pass a liquid crystal solidification object complex layer twice [at least] or more, the effectual scattering power of a transparency dispersion mold optical element improves. And when the liquid crystal optical element of a transparency dispersion mold is installed between the light source and an optical fiber with a reflective mold configuration, degradation of the extinction ratio and dynamic range resulting from interface reflection of each optical element which poses a problem is improved. Consequently, a high extinction ratio is obtained compared with the optical equipment using the transparency dispersion mold liquid crystal optical element and optical fiber of the conventional transparency mold component configuration and a reflective mold component configuration.
[0015] Moreover, while the electro-optics property of a liquid crystal optical element is stabilized, it can be made to always operate at the temperature from which the optimal electro-optics property is acquired by carrying out temperature control of the liquid crystal optical element compulsorily from a flesh-side substrate side.

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EXAMPLE

[Example]
(Example 1) An example explains concretely hereafter. The example 1 of this invention is shown in drawing 1 , and it explains with reference to this. The light guide of the light by which outgoing radiation was carried out from the light source installed outside as the light source is carried out from the optical fiber 51 for an input, and the liquid crystal optical equipment of an example 1 is introduced inside the liquid crystal optical element 30 from 1st prism object 2A of an input side through the input interface 55. 2nd prism object 2B, the output interface 56, and the optical fiber 52 for an output are mostly formed in the symmetry with the input side also at the output side.
[0017] What bundled the fiber of the numerical aperture (N.A.) 0.57 which uses multicomponent glass as a core as optical fibers 51 and 52 of the input side and output side which are used as a light guide means, and was used as the bundle fiber with a diameter of 5mm was used.
[0018] Parallel Guanghua of the light by which outgoing radiation was carried out from the bundle fiber 51 is carried out to the input interface 55 and the output interface 56 with a convex lens 55 using a convex lens, and parallel light is condensed on the outgoing radiation side bundle fiber 52 with the convex lens 56. Although the input interface 55, the output interface 56, the light guide means 51 and 52, prism object 2A, 2B, and the structure where 3 and 4 were joined are describing in drawing 1 -4, the light guide may be carried out through space as mentioned above.

[0019] In order to reduce firmer immobilization and interface reflected light loss, the structure which joined the input interface and the output interface to the light guide means and the prism object, respectively, using a refractive-index distribution pattern (gray TEDDO index) rod lens as an input interface and an output interface as shown in drawing 1 -4 is desirable. As for prism object 2A, 2B, and the liquid crystal optical element 30, it is desirable that a refractive index is a comparable optical material, and each is joined in optical adhesives with a comparable refractive index, or coupling oil.
[0020] When carrying out the light guide of the inside of a liquid crystal optical element using the total reflection in the front face of the front substrate 31 of the liquid crystal optical element 30, while a configuration is easy, about 100% of high reflection factor is obtained. However, critical angle thetac the incident angle within a front substrate (refractive index n) is described to be by the following (1) formula in order for total reflection to happen It must be more than (degree).
sin(thetac) =1/n (1)
[0021] Therefore, the include angle of prism object 2A, and the inclined plane of 2B and the front substrate of the liquid crystal optical element 30 to make must be carried out above (90 degree-thetac). When forming the reflective film in the front face of the front substrate 31 of the liquid crystal optical element 30, since there is no constraint like (1) type, its tolerance of formation of prism object 2A and 2B is on the other hand, wide.
[0022] The liquid crystal optical element 30 consists of the front substrate 31, transparent front electrode 30A, liquid crystal resin complex layer 30B, flesh-side electrode 30C that reflects light by non-transparence and makes a reflective means serve a double purpose, and a flesh-side substrate 32. The heat regulator is formed in the flesh-side substrate 32 side. Furthermore, it consists of a drive circuit which drives a liquid crystal optical element, ********** which carries

out drive control of the heat regulator.
[0023] The case in this example, by repeating reflection between flesh-side electrode 30C combining and [front / 31] and a reflective means, using the interface of the glass and air of the front substrate 31 of a liquid crystal optical element as a total reflection side, and passing a liquid crystal solidification object complex layer 4 times or more, scattering power can be improved further and an extinction ratio can be improved.
[0024] It is made for the total reflection in which the reflection by the interface of the vitreous front substrate 31 and air becomes settled with the refractive index of glass to happen like drawing 1 at this time. Or mirrors, such as metal mirrors, such as aluminum and silver, and a multilayer dielectric film, may be formed. As a normal reflective reduction means, the field of the front substrate 31 in which front electrode 30A is formed is made into the frosting side in which detailed irregularity was formed.
[0025] Next, it outlines about the configuration of the liquid crystal solidification object complex used by this invention. In the liquid crystal optical element in this invention, the liquid crystal display component which pinched the liquid crystal solidification object complex with which distributed maintenance of the nematic liquid crystal was carried out into the solidification object matrix is used. It is desirable to use the liquid crystal solidification object resin complex it was made mostly in agreement [complex] with the Tsunemitsu refractive index (no) of the liquid crystal which distributed maintenance of the nematic liquid crystal which has a forward dielectric anisotropy especially is carried out into a solidification object matrix, and the refractive index of the solidification object matrix uses. And liquid crystal solidification object complex is pinched between substrates with the electrode of a pair.
[0026] no of a nematic liquid crystal When the refractive-index anisotropy which is a difference with an extraordinary index (ne) is set to **n, as for **n, it is desirable that it is 0.18 or more. Moreover, in order to obtain scattering power with a high liquid crystal solidification object complex layer to the specific wavelength lambda (micrometer), it is desirable that the mean particle diameter R of liquid crystal (micrometer) has gathered according to the wavelength. In fact, it is desirable to fill the relation of ** n-R**lambda.
[0027] Therefore, when modulating the light of the wavelength band (lambda=0.4-0.7 (micrometer)) of the light using the bundle fiber for optical energy transmissions, in order for the scattering power in a liquid crystal solidification object complex layer to become homogeneity mostly in a full wave length region, it is desirable to be distributed over the range in which the mean particle diameter R of liquid crystal fills the relation of 0.4<**n-R<0.7.
[0028] When, using the light of the semiconductor laser diode of a non-light region, or the single wavelength of the near-infrared wavelength region (lambda=0.8-1.6 (micrometer)) of LED as a light on the other hand using the single track fiber for optical communication, or when using for optical measurement the light of the single wavelength of the helium-Ne laser which is the laser of a light oscillation, or semiconductor laser, the mean particle diameter R of liquid crystal has the desirable structure with little particle size distribution where ** n-R**lambda is filled.
[0029] As for the substrate with this electrode, that by which the electrode was prepared on substrates, such as glass, plastics, and a ceramic, is used. A transparent ingredient is used for the substrate by the side of plane of incidence at least in this invention. Glass is suitable for forming few still flatter and optical distorted substrate sides.
[0030] Between the substrates of a pair with an electrode, liquid crystal solidification object complex is pinched, respectively. Electric field occur by impression of an electrical potential difference, this liquid crystal solidification object complex changes the orientation of a liquid crystal molecule according to that electric field, and the refractive index of the liquid crystal in liquid crystal solidification object complex changes. When the refractive index of the solidification object matrix is mostly in agreement with the refractive index of liquid crystal, light penetrates, and light is scattered about when not in agreement. Since the liquid crystal optical element using this liquid crystal solidification object complex does not use the polarizing plate, an optical modulator with little optical loss is obtained.
[0031] The liquid crystal solidification object complex which specifically consists of a solidification object matrix by which a large number formation of the hole fine as a liquid crystal

display component was carried out, and a nematic liquid crystal with which the part of the hole was filled up is used. This liquid crystal solidification object complex is pinched between electrode substrates. The refractive index of the liquid crystal changes and the relation between the refractive index of a solidification object matrix and the refractive index of liquid crystal changes with the impression conditions of an electrical potential difference inter-electrode [the]. When these both refractive index is mostly in agreement, it will be in a transparency condition, and when refractive indexes differ, a liquid crystal optical element which will be in a dispersion condition can be used.

[0032] The liquid crystal solidification object complex which consists of a solidification object matrix by which a large number formation of this fine hole was carried out, and liquid crystal with which the part of that hole was filled up is the structure by which liquid crystal was confined in a liquid bubble like a microcapsule. However, each microcapsule does not need to be independent completely and the liquid bubble of each liquid crystal may be open for free passage through a slit like a porous body. Furthermore, the degree of a free passage may be high and in the condition which liquid crystal is opening for free passage in the shape of a stitch is sufficient.

[0033] The liquid crystal solidification object complex used for this invention is the following, and is made and manufactured. A nematic liquid crystal and the hardenability compound which constitutes a solidification object matrix are mixed, and it is made the shape of the shape of a solution, and a latex. Subsequently, what is necessary is for photo-curing, heat curing, hardening by solvent removal, reaction hardening, etc. to carry out this, to separate a solidification object matrix, and just to take the condition that the nematic liquid crystal distributed in the solidification object matrix.

[0034] Since the hardenability compound to be used can be hardened within a sealing system by making it photo-curing or a heat-curing type, it is desirable. When a photo-curing type hardenability compound is used especially, it cannot be influenced by heat, can be made to harden for a short time, and is desirable. After forming a cel using a sealant like the conventional usual nematic liquid crystal as a concrete process, pouring in non-hardened mixture [compound / a nematic liquid crystal and / hardenability] from an inlet and closing an inlet, it can heat whether an optical exposure is carried out and can also be made to harden.

[0035] Moreover, in the case of the liquid crystal optical element in this invention, non-hardened mixture [compound / a nematic liquid crystal and / hardenability] can be supplied on the substrate which prepared the transparent electrode as an electrode, not using a sealant, and another substrate with an electrode can also be stiffened by optical exposure etc. in piles after that. Of course, after that, a sealant may be applied on the outskirts and the seal of the circumference may be carried out. According to this process, in order for what is necessary to be just to only supply a roll coat, a spin coat, printing, spreading according non-hardened mixture [compound / a nematic liquid crystal and / hardenability] to a dispenser, etc., an impregnation process is simple and productivity is very good.

[0036] Moreover, into non-hardened mixture [compounds / these / nematic liquid crystals and hardenability compounds], spacers, such as a ceramic particle for substrate gap control, a plastics particle, and a glass fiber, a pigment, coloring matter, a viscosity controlling agent, and the other additives that do not have a bad influence on the engine performance of this invention may be added.

[0037] As mentioned above, although the manufacture approach by the photopolymerization method was shown, microencapsulation liquid crystal can also be formed also by the emulsion method.

[0038] Below, the other requirements for a configuration are explained. As front electrode 30A of the liquid crystal optical element 30, transparent electrodes, such as ITO, are formed on the vitreous front substrate 31 in which frosting processing was carried out by etching and polish with acid liquid. The irregularity formed of frosting processing should just be a configuration which reduces that normal reflection in the field finally reaches the light guide means 52 by the side of outgoing radiation.

[0039] Therefore, the irregularity of the shape of a rectangle in which many fields parallel to reflector 30C exist is unsuitable, and its irregularity of the shape of ** which is the aggregate of

the slant face which has a tilt angle is desirable. Although this tilt angle is related to the incident angle to the effective diameter of the light guide means 51 and 52, the input interface 55, the output interface 56, and a liquid crystal solidification object complex layer, the count of reflection, etc., generally as unnecessary interface reflection as the irregularity of the shape of sharp ** is removed, so that a tilt angle is perpendicularly near.
[0040] However, since surface area increases so that an acute angle, the rate of interface reflection increases and the transmitted light which can be used decreases. Therefore, the irregularity of the shape of ** with many inclination components which do not cause the remarkable decline in permeability but can reduce unnecessary interface reflection is desirable. Moreover, as a display device in this liquid crystal optical equipment, since the homogeneity of the property within a field is not required, the constraint about concavo-convex magnitude (pitch) is not so severe, but in the property of the amount of transmitted lights over applied voltage, when a sharper standup is needed like [in the case of an on-off control action], concavo-convex magnitude (pitch) is so desirable that it is small.
[0041] It is more desirable to make it into a big value, concavo-convex pitch, i.e., depth, and for the thickness of a liquid crystal solidification object complex layer to distribute on the other hand, since the property of the amount of transmitted lights over gently-sloping applied voltage is required for application of the dimmer which wants to control the middle quantity of light finely. in order to reduce further the interface reflectivity produced between the transparent electrodes and liquid crystal solidification object complex layers which were formed on the concave convex — a transparent electrode layer top — SiO2 MgF2 etc. — it is desirable to form a low refractive-index layer as an antireflection film. Moreover, the vitreous flesh-side substrate 32 which formed the aluminum film to serve also as an electrode as reflector 30C was used. It is good also as structure which carried out the laminating of the transparent electrode on the derivative multilayers mirror in addition to the metal membrane.
[0042] When using the total reflection produced in the interface of the reflector of the front substrate 31, and air, since a surface foreign matter and dirt become the cause of degrading total reflection effectiveness, it is desirable to form in a front face the film with a small refractive index, for example, the polymer which has a fluorine-containing aliphatic series ring structure, (trademark: SAITOPPU) as a protective coat from a front substrate ingredient.
[0043] Furthermore, when a liquid crystal solidification object complex layer is in a transparence condition, the reflector field where total reflection of the light is carried out with the front substrate 31 is only a part as shown in drawing 1 , but when a liquid crystal solidification object complex layer is in a dispersion condition, incidence of the scattered light is carried out to the larger range of an interface with the air of the front substrate 31. In order to remove such the unnecessary scattered light efficiently, it is effective to form light absorption objects, such as a black coating, in addition to the total reflection field needed.
[0044] Moreover, the heat sink by which the temperature sensor and the electrical heater were built in the background of the reflector of a liquid crystal optical element was pasted up. Furthermore, the fan for air cooling was attached behind this heat sink, and it could be made to carry out by the electrical heater and the fan for air cooling the temperature control, acting as the monitor of the temperature so that a liquid crystal optical element may be maintained by laying temperature.
[0045] The light guide of the sources of the light, such as a halogen lamp, Xe lamp, and a metal halide lamp, was carried out to the incidence side optical fiber 51, and it considered as incident light. Alternating voltage was impressed to inter-electrode [of the aforementioned liquid crystal optical element 30] for the 100Hz square wave, and it considered as the dimmer by modulating an effective voltage value by the external circuit, and changing the transparency dispersion condition of a liquid crystal optical element. The optical property was measured using the liquid crystal optical equipment using the liquid crystal optical display device of the optical fiber of this invention produced with such a configuration, and a transparency dispersion mold. The result was summarized in Table 1.
[0046] In Table 1, relative light transmittance makes the example of a comparison 100%. moreover, measurement — constant temperature — carried out within a degree tub,

temperature means not the temperature of a liquid crystal display component but the ambient temperature of optical equipment, and a measurement extinction ratio shows the range of the light value ratio of the outgoing radiation side fiber 52 to the applied-voltage values 0V and 30V of the liquid crystal optical element in a 0 to 50 degrees C temperature requirement. Same optical property evaluation was performed about the thing of a configuration of having made the table electrode 30A page into the flat side among the liquid crystal optical elements of a configuration of having been shown in the example 1 as an example of a comparison, and the result was indicated.
[0047]
[Table 1]

	不要な正規反射光除去手段	相対的光透過率	消光比	応答速度（ｍｓｅｃ）
実施例１	フロスト面あり	９８％	２５０～２８０	１５
比較例１	フロスト面なし	１００％	３～　１５	１５～２００

[0048] This result shows that the improvement in fast of an extinction ratio and stability are attained by the configuration of this invention while optical loss has been almost small. Therefore, adjustment of the outgoing radiation quantity of light corresponding to an applied-voltage value can carry out to a high speed arbitrarily [there is little quantity of light loss and] by using this optical equipment as a dimmer.
[0049] Moreover, the optical outgoing radiation edge of an outgoing radiation side optical fiber is turned to an illuminated object, and this liquid crystal optical equipment installs it, and when carrying out optical high measurement of a S/N ratio by the lock-in amplifier, it can use the electrical signal of photodetectors, such as the photomultiplier tube and Si photodiode, as a required fiber type light chopper. Compared with a conventional pivoted window type chopper or a conventional oscillatory type chopper, small and high-speed optical chopping becomes possible.
[0050] Metallic reflection mirrors, such as aluminum, are sufficient as reflector 30C, and an optical interference multilayers reflecting mirror is sufficient as it. In the case of the former, in order that a reflector may serve also as an electrode, manufacture is easy, and a component can be constituted without complicating structure. In the case of the latter, it is also possible to form the cold mirror which has the spectral characteristic which penetrates a heat ray and reflects only the light by the configuration of multilayers, and it has the degree of freedom which can also form the mirror of 100% of reflection factors to the specific semiconductor laser wavelength used by optical communication.
[0051] (Example 2) It explains using drawing 2 . In this example, unlike the configuration of an example 1, each of front electrode 30A and flesh-side electrode 30C is transparent electrodes, and it is a flat side mostly [both]. Moreover, by opening enough the distance d of liquid crystal solidification object complex layer 30B and the reflector of a reflective means The optical path of the normal reflected light which produces the optical path of the normal reflected light produced in an interface with the field of liquid crystal solidification object complex layer 30B of thickness t, transparent front electrode 30A, and flesh-side electrode 30B in the field of a liquid crystal optical element is shifted to the field inboard of a liquid crystal optical element. The unnecessary interface reflected light can be prevented from reaching the light guide means 52 by the side of outgoing radiation.
[0052] This shift-amount delta is described to be delta=2d-tantheta by the distance d of the incident angle theta of the incident light to liquid crystal solidification object complex layer 30B, and the reflector of a reflective means. In order not to make the unnecessary interface reflected light reach the outgoing radiation side light guide means 52, shift-amount delta should just be more than the exposure width of face L of the incident light to liquid crystal solidification object

complex layer 30B. Thus, if shift-amount delta required to remove the unnecessary interface reflected light becomes settled, spacing d can be found according to it. Since a liquid crystal optical element will be enlarged if thickness d more than fixed is needed when the function as a substrate of one side holding a liquid crystal solidification object complex layer is also taken into consideration, and d is made into a big value on the other hand, about d= 0.5-30mm is desirable in fact.
[0053] Moreover, in this example, the refractive-index distribution pattern (gray TEDDO index) rod lens was used as the input interface 55 and an output interface 56, using quartz system single-mode optical fiber with a core diameter [for optical-communication information transmissions] of 10 micrometers as light guide means 51 and 52. Optical fiber guided wave light used the semiconductor laser light of the wavelength of 1.3 micrometers, and 1.5-micrometer near-infrared region. Prism object 2A and 2B are joined to the front substrate 31 of the input interface 55, the output interface 56, and the liquid crystal optical element 30 with optical adhesives, as respectively shown in drawing 2 .
[0054] Moreover, the dielectric multilayer reflecting mirror which reflects the light of the wavelength band of guided wave light only in the reflector part of the front face of the front substrate 31 of the liquid crystal optical element 30 99% or more is formed, and the light absorption object is applied to the front face of other front substrates 31. In order to perform reflection in the front face of the front substrate 31 not by total reflection but by the dielectric multilayer reflecting mirror, it is not necessary to fill with this example the total reflection conditions described by (1) formula.
[0055] Therefore, in order to prevent carrying out total reflection of the guided wave light with unnecessary scattered light in liquid crystal solidification object complex layer 30B, wavelength light other than guided wave light, etc. on the front face of the front substrate 31, and a part guiding waves (1) Critical angle thetac which becomes settled by the formula It determined that the tilt angle of prism object 2A and 2B carried out incidence to liquid crystal solidification object complex layer 30B by the small incident angle, and the rate that an unnecessary light guides the liquid crystal optical element 30 interior was reduced.
[0056] In this example, it considered as the thickness of about 20 micrometers of liquid crystal solidification object complex layer 30B, and boro-silicated glass of about 1mm of board thickness was used for the front substrate 31 and the flesh-side substrate 32. Consequently, the high extinction ratio of 106 more than and the speed of response of 2 or less msecs were stabilized, and were obtained.
[0057] (Example 3) It explains using drawing 3 . Unlike the configuration of an example 1, in this example, both the field of front electrode 30A and the field of flesh-side electrode 30C are almost flat. Light is reflected by the light reflex means 90 of the dedication prepared in the rear-face side of the flesh-side substrate 32. Moreover, unnecessary interface reflection of the liquid crystal optical element 30 interior is removable by not supposing that transparent front electrode 30A and flesh-side electrode 30C which touch liquid crystal solidification object complex layer 30B are parallel to the light reflex means 90, but attaching whenever [suitable tilt-angle].
[0058] Since the flat profile irregularity of a substrate is not required so much in the case of this invention which is made to transmit due to about 1 to 1, without converging light, it is satisfactory even if it uses a long film formation technique using a cheap film-like substrate with sheet metal like a PET film.
[0059] In this example, it is arranged so that the unnecessary normal reflected light of the interface in the liquid crystal solidification object complex layer 30B may carry out incidence to the outgoing radiation side optical fiber 52, and may not cause degradation of an extinction ratio, and front electrode 30A, liquid crystal solidification object complex layer 30B, the field side of flesh-side electrode 30C, and the reflector 90 of a light reflex means may incline.
[0060] The tilt angle alpha will not carry out incidence of the unnecessary reflected light produced in the interface of a liquid crystal solidification object complex layer to the light guide means 52, if it is set as the liquid crystal solidification object complex layer which becomes settled with the effective diameter of the light guide means 51 and 52, and the focal distance of

close and the output interfaces 55 and 56 to the distributed angle theta of the parallel light which carries out incidence more than theta.
[0061] Since N.A. is also small, the range of alpha of 0.1 degrees - 10 degrees is [whenever / tilt-angle] desirable [a core diameter is as thin as 200 micrometers or less, and] in the case of the single track fiber for optical communication. Since it uses as a bundle fiber etc. in the case of the fiber for optical energy transmissions, and the diameter of a fiber of the optical transmission section is as thick as about 2-20mm, the range of alpha of 1 degree - 20 degrees is [whenever / tilt-angle] on the other hand, desirable.
[0062] Furthermore, although the interface reflected light is removed also when it considers as whenever [big tilt-angle / alpha], the light which carries out incidence from across becomes most at a liquid crystal solidification object complex layer, and effectual permeability falls that it is easy to produce Hayes accompanying index mismatching at the time of transparence. Moreover, since a liquid crystal optical element will become thick and the magnitude and weight of the whole equipment will increase if alpha becomes large whenever [tilt-angle], limiting to the above-mentioned range is [whenever / tilt-angle] desirable [alpha].
[0063] Since the bundle fiber with a same effective diameter [as an example 1] of 5mm and the convex lens with a focal distance of 30mm were used, the distributed angle theta of the parallel light which carries out incidence to a liquid crystal solidification object complex layer became about 10.6 degrees, and made 12 degrees of liquid crystal solidification object complex layers incline to the reflector of a light reflex means in this example.
[0064] In this example, in order to perform a temperature control to accuracy more and to secure the repeatability of an optical property also to large environmental temperature, the reflecting mirror was used as the cold mirror and the heat sink where the Peltier device and temperature sensor of electronics control were embedded as a heat regulator 60 was used.
[0065] When the configuration of drawing 3 estimated the optical property, while the extinction ratio 320 was always obtained from -20 degrees C in the large environmental temperature of 80 degrees C, the result of having been stabilized by the applied-voltage pair optical output property to the temperature change was obtained. Moreover, compared with the thing of aluminum nature, since the reflection factor was high about 10%, as for relative light transmittance, the direction of cold mirror nature became a high value compared with the example 1 of a comparison.
[0066] Furthermore, in the liquid crystal optical equipment of the configuration of an example explained above, it has composition which may be able to carry out forcible temperature control of the liquid crystal optical element 30 from a reflector side (background of the flesh-side substrate 32). As a compulsive temperature control method, it equips with a heat sink and cools with an air cooling fan. Or it can equip with a Peltier device, an electrical heater, and a temperature sensor, and temperature control can also be depended and carried out to heating and cooling so that it may be maintained by fixed temperature.
[0067] (Example 4) The example 4 of this invention is explained using drawing 4 . In this example, it consists of a liquid crystal optical element 30 of the incidence side optical fiber 51 and the outgoing radiation side optical fiber 52, the prism object 3 equipped with the total reflection side of a V type, and the reflective mold that functions as the light modulation section, and a heat regulator 60 using the single track optical fiber for optical communication, and consists of an electronic circuitry which carries out drive control of the drive circuit and heat regulator 60 which drive a liquid crystal optical element further.
[0068] Moreover, it consisted of the 1st interface 55 or 2nd interface 56 etc. which serves as the liquid crystal optical element 30 and the prism object 3 from a rod lens, and each optical element is pasted up on one with optical adhesives.
[0069] Frosting processing of the glass side of a substrate 31 in which transparent front electrode 30A (ITO etc.) by the side of the optical plane of incidence of the liquid crystal optical element 30 or an outgoing radiation side is formed is carried out. On the flesh-side substrate 32 with which the optical interference multilayers mirror which reflects the luminescence wavelength of specific LD (laser diode) or LED which is incident light as a reflector was formed, the transparent electrode was formed and the opposite substrate was formed. As an optical fiber

by the side of the incidence of a liquid crystal optical element, and outgoing radiation, it is the quartz system fiber of FC connector connection mold, and the step mold refractive-index distribution optical fiber for multi-mode transmission with a core diameter of 50 micrometers was used.
[0070] As an input interface and an output interface, the rod lens (NSG: SELFOC lens) of diameter =1.8mm, pitch =1/4, and the gray TEDDO index mold for wavelength 830nmLD of lens length =4.73mm was used for each.
[0071] After reflecting an almost parallel light by which outgoing radiation was carried out from the input interface 55 (rod lens) by one prism total reflection side 3a, using BK7 of optical glass as a prism object, incidence is carried out to the liquid crystal optical element 30 of a reflective mold by about 18-degree incident angle. After reflecting the normal reflected light reflected with the reflective means (flesh-side electrode 30C is made to serve a double purpose) by another prism total reflection side 3b, the light guide is carried out with an output interface. It is further condensed by the end face of the optical fiber 52 by the side of outgoing radiation, and this light turns into outgoing radiation light.
[0072] In this example, the always stabilized optical property was obtained in large environmental temperature like the example 2 using the heat sink where the Peltier device and temperature sensor of electronics control were embedded as a heat regulator 60. The result of having measured the optical property was summarized in Table 2 using the optical fiber of this invention and the **** liquid crystal optical equipment for transparency dispersion mold display devices which were produced with such a configuration. In Table 2, relative light transmittance makes the example of a comparison 100%.
[0073] moreover, measurement — constant temperature — carried out within the degree tub, temperature meant not the temperature of a liquid crystal display component but the ambient temperature of optical equipment, and evaluated the measurement extinction ratio and the speed of response to the applied-voltage values 0V and 100V of a liquid crystal optical element in the -20 to 60 degrees C temperature requirement.
[0074] As an example of a comparison, the flat side of the ITO electrode surface by the side of the optical incidence of the liquid crystal optical element which is a configuration conventionally was carried out, and the same optical property evaluation result was indicated also about the thing of a configuration of not carrying a heat regulator 60.
[0075]
[Table 2]

	不要な正規反射光除去手段	相対的光透過率	消光比	応答速度 (msec)
実施例3	傾斜角度	99%	30000	1.5
比較例2	なし	100%	5〜25	1.5〜100

[0076] From this result, the configuration of this invention shows that the improvement in fast of an extinction ratio and stability are attained, while there has almost been no optical loss. Therefore, by using this optical equipment as a good light variation attenuator for optical communication, there is little quantity of light loss and adjustment of the outgoing radiation quantity of light corresponding to an applied-voltage value can carry out to a high speed arbitrarily.
[0077] Other configurations may be used although the configuration using the prism object 3 which has the total reflection side of a V type described in this example. For example, an optical path may be bent according to the spherical surface or the aspheric surface. Moreover, an extinction ratio is also further improvable by considering as the configuration which changed the ratio of the configuration of the total reflection side of the prism object 3, and the core diameter of an optical fiber.

[0078] (Example 5) An example 5 is explained using drawing 5 . In this example, by carrying out incidence of the optical fiber for an input, and the almost parallel light by which outgoing radiation was carried out to the prism object 4 from the interface 55 (rod lens) for an input with the prism object 4 of a trapezoid configuration by the suitable incident angle for the liquid crystal optical element 30 of a reflective mold, total reflection is carried out by flesh-side electrode 30C, and total reflection is again carried out by top total reflection side 4a of the prism object 4. And if the prism object 4 is arranged in a suitable location, reflection will be rewound two or more times in respect of the reflector of a liquid crystal optical element, and total reflection, and light will be outputted to the interface 56 for an output by the side of outgoing radiation the back the bottom.
[0079] With such a configuration, an extinction ratio can be further raised compared with the configuration in the conventional example which passes light only twice by passing a liquid crystal solidification object complex layer 4 times or more. Although drawing 5 is describing the case where a liquid crystal solidification object complex layer is passed 4 times, the count of passage is changeable into arbitration by the multiple of 2 by changing suitably the die length (the die length of the longitudinal direction of top-face 4a) and the incident angle of the prism object 4.
[0080] The same configuration as an example 1 is sufficient as the liquid crystal optical element 30 of a reflective mold, and it may not form a reflector in contact with liquid crystal solidification object complex layer 30B like an example 2 or an example 3, but may establish the light reflex means by the external reflector. In this case, what is necessary is for what both sides of a front electrode and a flesh-side electrode are made into a frosting side, you prepare spacing with the reflector of a light reflex means in a liquid crystal solidification object complex layer like an example 2 as a normal reflective reduction means, or is made for the reflector of a light reflex means and liquid crystal solidification object complex layer 30B to incline suitably like an example 3 (refer to drawing 3) just to remove interface reflection with liquid crystal solidification object complex layer 30B and an electrode surface.
[0081] About 2-200 micrometers is desirable, and concavo-convex magnitude (pitch) is concavo-convex depth (ten-point average depth) RZ. About 0.1-10 micrometers is desirable. Moreover, when light carries out incidence from across to a liquid crystal solidification object complex layer in this way, it is desirable that index matching with the liquid crystal at the time of transparence makes it whenever [optical incident angle] most at the optimal (as [decrease / namely, / Hayes]) combination.
[0082] As mentioned above, although the example was explained, an approximate account is performed about the magnitude of each part etc. next. In transmitting light energy, a halogen lamp, a metal halide lamp, Xe lamp, etc. are used as the light source, and in order for all to condense efficiently using a condensing means and for luminescence length to do a light guide to a fiber about 2-10mm for a certain reason, the fiber diameter of about 3-10mm is needed.
[0083] Moreover, the magnitude of the light source has the width of face of 10-30cm (500W-3kW) extent from die length of 3-10cm (10W - 500W class), and the magnitude of a converging mirror will also be doubled according to the classification of the light source. And although the magnitude of a liquid crystal optical element is decided according to N.A. of the magnitude, for example, the focal distance and effective diameter, and the fibers of the condensing means to be used (an ellipse mirror, lens, etc.) etc., when using the above-mentioned light source, it is about considered about 1-30cm of vertical angles.
[0084] In using for the purposes, such as a communication link and optical measurement, the incidence aperture of light is 1mm or less, and the diameter is set to 1cm or less even if it uses a lens, since the emission light of laser die auto or LED is condensed. Since the optical transmission section core diameter of the single track fiber for optical communication is 200-micrometer or less extent, the magnitude of a liquid crystal optical element is set to about about 1-5cm.

[Translation done.]

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DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] The mimetic diagram of the cross section of the liquid crystal optical equipment of the example 1 (concave convex) of this invention.
[Drawing 2] The mimetic diagram of the cross section of the liquid crystal optical equipment of the example 2 (thickness) of this invention.
[Drawing 3] The mimetic diagram of the cross section of the liquid crystal optical equipment of the example 3 (inclination) of this invention.
[Drawing 4] The mimetic diagram of the cross section of the liquid crystal optical equipment of the example 4 (V type prism) of this invention.
[Drawing 5] The mimetic diagram of the cross section of the liquid crystal optical equipment of the example 5 (trapezoidal prism) of this invention.
[Drawing 6] The top view showing the configuration in the conventional example.
[Description of Notations]
2A: Input-side prism object
2B: Output side prism object
30: Liquid crystal optical element
30A: Front electrode
30B: Liquid crystal solidification object complex layer
30C: Flesh-side electrode
31: Front substrate
32: Flesh-side substrate
51: Input-side optical fiber
52: Output side optical fiber
55: Input-side interface
56: Output side interface
60: Heat regulator

[Translation done.]

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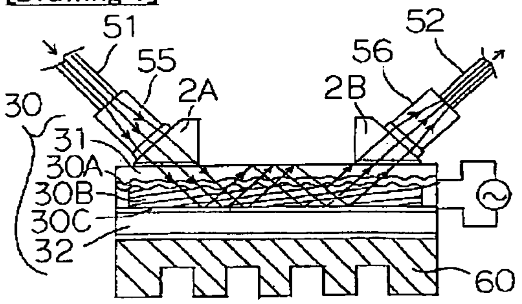
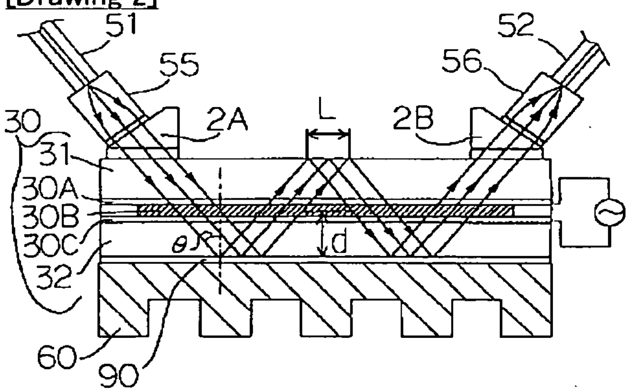
DRAWINGS

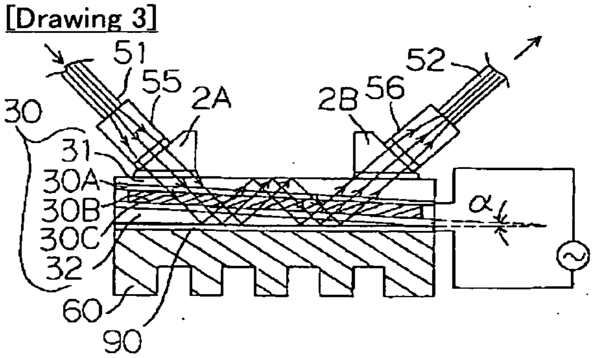
[Drawing 1]



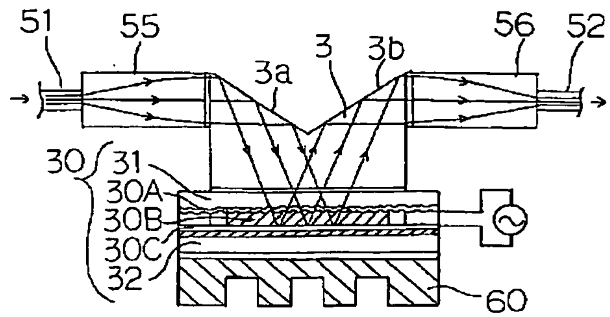
[Drawing 2]



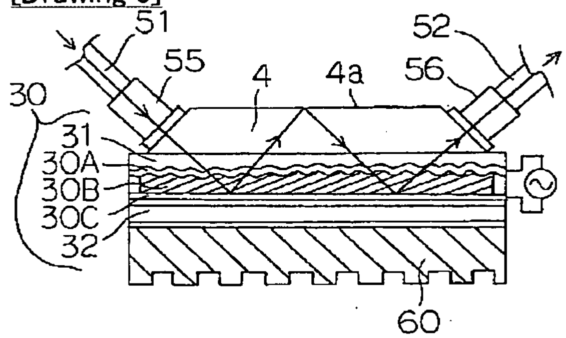
[Drawing 3]



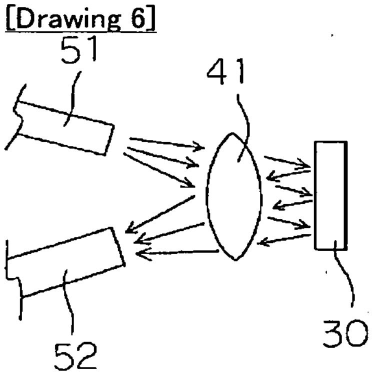
[Drawing 4]



[Drawing 5]



[Drawing 6]



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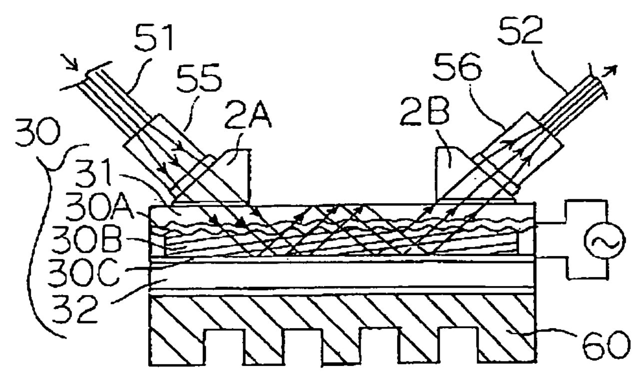
(54)【発明の名称】　液晶光学装置およびそれを用いた照明装置

(57)【要約】

【目的】高効率の光変調器を得る。

【構成】光ファイバ５１，５２と、ロッドレンズ５５，５６と、プリズム体２Ａ，２Ｂと、表基板３１、表電極３０Ａ、液晶固化物複合体層３０Ｂ、反射手段にもなる裏電極３０Ｃ、裏基板３２からなる液晶光学素子３０とが設けられ、光路中の凹凸界面か、液晶固化物複合体層に対し基板間隙を十分をとるか、反射面と挟角αをなす界面が備えられ、液晶固化物複合体層３０Ｂを光が２回以上通過せしめられてなる液晶光学装置。



【特許請求の範囲】

【請求項１】光源と、第一の導光手段と、第一のプリズム体と、

表電極が形成された表基板と裏電極が形成された裏基板の間に、液晶が固化物マトリックス中に分散保持された液晶固化物複合体が挟持され、両電極間に発生する電界によって液晶が制御され、液晶の屈折率が固化物マトリックスの屈折率に一致しない際に光が散乱し、液晶の屈折率が固化物マトリックスの屈折率とほぼ一致した際に光が透過する液晶固化物複合体層を備えた液晶光学素子と、

光反射手段と、

第二のプリズム体と、

第二の導光手段とが設けられ、

光源から第二の導光手段に至る光路の途中に光反射手段が配置され、

液晶固化物複合体層は光反射手段の反射面側に近接して配置されるか、もしくは反射面に密着して配置され、

光源から出射された光は第一の導光手段を通過して第一のプリズム体を介して液晶光学素子の第一の面の入射部から液晶光学素子の内部へ入射せしめられ、

第一の面の反射部または光反射手段でそれぞれ１回以上反射され、最後に第一の面の出射部から出射され、

さらに第二のプリズム体を介して第二の導光手段に入射せしめられ、

入射部から出射部に至るまでに液晶固化物複合体層を２^{n} 回（ｎ＝１以上の整数）通過せしめられ、このさいに液晶固化物複合体層の光の透過度によって光量が制御され、

液晶光学素子内部での光路に交わる界面のうちの少なくとも一つの界面に凹凸が設けられるか、

または、液晶光学素子の液晶固化物複合体層と光反射手段との間隔ｄを液晶固化物複合体層の厚さｔに対して１０倍以上とされるか、

または、液晶光学素子内部での光路に交わる界面のうちの少なくとも一つの界面が光反射手段の反射面に対して所定の角度αだけ傾斜せしめられたことを特徴とする液晶光学装置。

【請求項２】光源と、第一の導光手段と、

表電極が形成された表基板と裏電極が形成された裏基板の間に、液晶が固化物マトリックス中に分散保持された液晶固化物複合体が挟持され、両電極間に発生する電界によって液晶が制御され、液晶の屈折率が固化物マトリックスの屈折率に一致しない際に光が散乱し、液晶の屈折率が固化物マトリックスの屈折率とほぼ一致した際に光が透過する液晶固化物複合体層を備えた液晶光学素子と、

光反射手段と、

第二の導光手段と反射面を備えたプリズム体とが設けられ、

光源から第二の導光手段に至る光路の途中に光反射手段が配置され、

液晶固化物複合体層は光反射手段の反射面側に近接して配置されるか、もしくは反射面に密着して配置され、

光源から出射された光は第一の導光手段を通過せしめられ、プリズム体の入射面からプリズム体内部へ導光され、さらに液晶光学素子の第一の面の入射部から液晶光学素子の内部へ入射せしめられ、

プリズム体の反射面、または光反射手段でそれぞれ１回以上反射され、最後にプリズム体の出射面から第二の導光手段に入射せしめられ、

プリズム体の入射面からプリズム体の出射面に至るまでに液晶固化物複合体層を２^{n} 回（ｎ＝１以上の整数）通過せしめられ、このさいに液晶固化物複合体層の光の透過度によって光量が制御され、

液晶光学素子内部での光路に交わる界面のうちの少なくとも一つの界面に凹凸が設けられるか、

または、液晶光学素子の液晶固化物複合体層と光反射手段との間隔ｄを液晶固化物複合体層の厚さｔに対して１０倍以上とされるか、

または、液晶光学素子内部での光路に交わる界面のうちの少なくとも一つの界面が光反射手段の反射面に対して所定の角度αだけ傾斜せしめられたことを特徴とする液晶光学装置。

【請求項３】請求項１または２の、界面に凹凸が設けられた液晶光学装置において、表電極のなす界面に凹凸が形成されたことを特徴とする液晶光学装置。

【請求項４】請求項１～３のいずれか１項の、界面に凹凸が設けられた液晶光学装置において、裏電極のなす界面に凹凸が形成されたことを特徴とする液晶光学装置。

【請求項５】請求項１～３のいずれか１項の、界面に凹凸が設けられた液晶光学装置において、光反射手段は液晶光学素子のほぼ平坦な裏電極と兼用されてなることを特徴とする液晶光学装置。

【請求項６】請求項１～５のいずれか１項の液晶光学装置において、裏基板側にさらに温度調整器が設けられたことを特徴とする液晶光学装置。

【請求項７】請求項１～６のいずれか１項の液晶光学装置を備えた照明装置。

【発明の詳細な説明】

【０００１】

【産業上の利用分野】本発明は、光ファイバおよび液晶固化物複合体を備えた透過散乱型の液晶光学素子を用いた液晶光学装置、およびそれを用いた照明装置に関する。

【０００２】

【従来の技術】従来から光源と光伝送用の光ファイバとの間に液晶光学素子を配置して、液晶光学素子により光源から光ファイバに伝達される光量を制御する液晶光学装置が知られている。さらに、光エネルギー伝送用の光

ファイバ、または単線の光ファイバを束ねた光ファイババンドルと光源と液晶光学素子とを用いた照明装置や配光装置が提案されている。

【0003】また、光源から液晶光学素子への導光手段に光ファイバを用い、光ファイバと光ファイバとの間に液晶光学素子を配置した構成が提案されている。図6に従来例としてその基本配置を示す。入射用の光ファイバ51と出射用の光ファイバ52と凸レンズ41と、反射型手段と液晶固化物複合体とを備えた透過散乱型の動作モードを示す液晶光学素子30とから構成されている。そして、この構成により光の変調を達成することができる。

【0004】また、この従来例と似たような配置構成であるが、光通信情報伝送用の低損失細線光ファイバを液晶光学素子の光入射側および光出射側に用いた光可変減衰器が提案されている。以上のように、透過散乱型の動作モードを有し偏光板なしで光の制御を行うことのできる液晶固化物複合体を備えた液晶光学素子を用いることにより光損失の低減が可能となることから、反射型液晶光学素子とレンズを用いても光可変減衰器が構築可能であることが提案されている。

【0005】

【発明が解決しようとする課題】この場合、反射型の構成とすることによって液晶固化物複合体層を光が2回通過するため、液晶固化物複合体自体の散乱能は1回のみ光が通過する透過型の構成に比べ飛躍的に向上する。

【0006】しかし、液晶光学素子の界面および集光用レンズの界面などにおいて生じる界面反射の一部が光出射側の光ファイバに常時入射するため、液晶固化物複合体が散乱状態の時、光ファイバからの出射光量は低くならず、液晶固化物複合体層への電圧印加および非印加による出射光の消光比は透過型の構成に比べ高いとはいえなかった。

【0007】したがって、液晶光学素子の電圧印可に伴なう光量変化のダイナミックレンジは透過型の素子構成に比較して改善されることはほとんどなく低い特性値のままであった。また、多量の光を放出する光源を用いた場合、放射熱などに伴う液晶光学素子の温度上昇は著しく、各種の電気光学特性（印加電圧対光透過率の特性、ダイナミック応答特性、消光比等）の再現性が低くなり正確な調光が困難となった。

【0008】

【課題を解決するための手段】本発明は、光源と、第一の導光手段と、第一のプリズム体と、表電極が形成された表基板と裏電極が形成された裏基板の間に、液晶が固化物マトリックス中に分散保持された液晶固化物複合体が挟持され、両電極間に発生する電界によって液晶が制御され、液晶の屈折率が固化物マトリックスの屈折率に一致しない際に光が散乱し、液晶の屈折率が固化物マトリックスの屈折率とほぼ一致した際に光が透過する液晶固化物複合体層を備えた液晶光学素子と、光反射手段と、第二のプリズム体と、第二の導光手段とが設けられ、光源から第二の導光手段に至る光路の途中に光反射手段が配置され、液晶固化物複合体層は光反射手段の反射面側に近接して配置されるか、もしくは反射面に密着して配置され、光源から出射された光は第一の導光手段を通過して第一のプリズム体を介して液晶光学素子の第一の面の入射部から液晶光学素子の内部へ入射せしめられ、第一の面の反射部または光反射手段でそれぞれ1回以上反射され、最後に第一の面の出射部から出射され、さらに第二のプリズム体を介して第二の導光手段に入射せしめられ、入射部から出射部に至るまでに液晶固化物複合体層を2^n回（n＝1以上の整数）通過せしめられ、このさいに液晶固化物複合体層の光の透過度によって光量が制御され、液晶光学素子内部での光路に交わる界面のうちの少なくとも一つの界面に凹凸が設けられるか、または、液晶光学素子の液晶固化物複合体層と光反射手段との間隔dを液晶固化物複合体層の厚さtに対して10倍以上とされるか、または、液晶光学素子内部での光路に交わる界面のうちの少なくとも一つの界面が光反射手段の反射面に対して所定の角度αだけ傾斜せしめられたことを特徴とする液晶光学装置（1）を提供する。

【0009】また、光源と、第一の導光手段と、表電極が形成された表基板と裏電極が形成された裏基板の間に、液晶が固化物マトリックス中に分散保持された液晶固化物複合体が挟持され、両電極間に発生する電界によって液晶が制御され、液晶の屈折率が固化物マトリックスの屈折率に一致しない際に光が散乱し、液晶の屈折率が固化物マトリックスの屈折率とほぼ一致した際に光が透過する液晶固化物複合体層を備えた液晶光学素子と、光反射手段と、第二の導光手段と反射面を備えたプリズム体とが設けられ、光源から第二の導光手段に至る光路の途中に光反射手段が配置され、液晶固化物複合体層は光反射手段の反射面側に近接して配置されるか、もしくは反射面に密着して配置され、光源から出射された光は第一の導光手段を通過せしめられ、プリズム体の入射面からプリズム体内部へ導光され、さらに液晶光学素子の第一の面の入射部から液晶光学素子の内部へ入射せしめられ、プリズム体の反射面、または光反射手段でそれぞれ1回以上反射され、最後にプリズム体の出射面から第二の導光手段に入射せしめられ、プリズム体の入射面からプリズム体の出射面に至るまでに液晶固化物複合体層を2^n回（n＝1以上の整数）通過せしめられ、このさいに液晶固化物複合体層の光の透過度によって光量が制御され、液晶光学素子内部での光路に交わる界面のうちの少なくとも一つの界面に凹凸が設けられるか、または、液晶光学素子の液晶固化物複合体層と光反射手段との間隔dを液晶固化物複合体層の厚さtに対して10倍以上とされるか、または、液晶光学素子内部での光路に

交わる界面のうちの少なくとも一つの界面が光路の中心軸に対して所定の角度αだけ傾斜せしめられたことを特徴とする液晶光学装置（２）を提供する。

【００１０】また、上記の液晶光学装置（１）または（２）の、界面に凹凸が設けられた液晶光学装置において、表電極のなす界面に凹凸が形成されたことを特徴とする液晶光学装置（３）を提供する。また、上記の液晶光学装置（１）～（３）のいずれか１つの、界面に凹凸が設けられた液晶光学装置において、裏電極のなす界面に凹凸が形成されたことを特徴とする液晶光学装置（４）を提供する。

【００１１】また、上記の液晶光学装置（１）～（３）のいずれか１つの、界面に凹凸が設けられた液晶光学装置において、光反射手段は液晶光学素子のほぼ平坦な裏電極と兼用されてなることを特徴とする液晶光学装置（５）を提供する。また、上記の液晶光学装置（１）～（５）のいずれか１つの液晶光学装置において、裏基板側にさらに温度調整器が設けられたことを特徴とする液晶光学装置（６）を提供する。さらに、上記の液晶光学装置（１）～（６）のいずれか１つの液晶光学装置を備えた照明装置を提供する。

【００１２】本発明の液晶光学装置においては、不要な正規反射光低減手段として液晶光学素子の透明電極面に微細な凹凸が形成されるか、または、液晶光学素子の液晶固化物複合体層と光反射手段との間隔ｄを液晶固化物複合体層の厚さｔに対して１０倍以上とする。液晶光学素子の液晶固化物複合体層を光反射手段の反射面に対し傾斜角度を設ける。これらの不要反射低減手段によって、液晶固化物複合体層と透明電極付き基板ガラスとの界面などにおいて生じる正規反射の内、第二の導光手段に入射する成分が低減される。

【００１３】また、プリズム体と液晶光学素子との間の界面による正規反射光を積極的に抑制するように、一体的な構造を採用し、コンパクトかつ機械的に強固であり光学的に優れた液晶光学装置を提供する。

【００１４】

【作用】本発明によれば、光が固体媒体中のみを通過し、液晶固化物複合体層を少なくとも２回以上通過するため、透過散乱型光学素子の実効的散乱能が向上する。そして、透過散乱型の液晶光学素子を反射型構成で光源と光ファイバとの間に設置したときに問題となる各光学素子の界面反射に起因する消光比およびダイナミックレンジの劣化が改善される。その結果、従来の透過型素子構成および反射型素子構成の透過散乱型液晶光学素子と光ファイバを用いた光学装置に比べて、高い消光比が得られる。

【００１５】また、裏基板側から液晶光学素子を強制的に温度制御することにより、液晶光学素子の電気光学特性が安定するとともに最適な電気光学特性が得られる温度で常に動作させることができる。

【００１６】

【実施例】

（実施例１）以下、実施例により具体的に説明する。本発明の実施例１を図１に示し、これを参照して説明する。実施例１の液晶光学装置は、光源として外部に設置された光源から出射された光が入力用光ファイバ５１から導光され、入力インターフェース５５を経て入力側の第１のプリズム体２Ａから液晶光学素子３０の内部へ導入される。出力側にも入力側とほぼ対称に第２のプリズム体２Ｂと出力インターフェース５６、出力用光ファイバ５２が設けられている。

【００１７】導光手段として用いられる入力側および出力側の光ファイバ５１，５２としては、多成分ガラスをコアとする開口数（Ｎ．Ａ．）０．５７のファイバを束ねて直径５ｍｍのバンドルファイバとしたものを用いた。

【００１８】入力インターフェース５５および出力インターフェース５６には凸レンズを用い、バンドルファイバ５１から出射された光を凸レンズ５５で平行光化し、凸レンズ５６で平行光を出射側バンドルファイバ５２に集光している。図１～４では入力インターフェース５５、出力インターフェース５６と導光手段５１および５２とプリズム体２Ａ，２Ｂ，３および４が接合された構造で記されているが、上述のように空間を介して導光されていてもよい。

【００１９】より強固な固定および界面反射光損失を低減するためには、図１～４に示すように屈折率分布型（グレーテッドインデックス）ロッドレンズを入力インターフェースおよび出力インターフェースとして用い、入力インターフェースおよび出力インターフェースをそれぞれ導光手段とプリズム体に接合した構造が好ましい。プリズム体２Ａ，２Ｂと液晶光学素子３０は屈折率が同程度の光学材料であることが好ましく、それぞれは屈折率が同程度の光学接着剤またはカップリングオイルで接合されている。

【００２０】液晶光学素子３０の表基板３１の表面での全反射を利用して液晶光学素子内を導光する場合、構成が簡単であるとともにほぼ１００％の高い反射率が得られる。ただし、全反射が起こるためには表基板（屈折率ｎ）内での入射角が、次の（１）式で記述される臨界角θ_c（°）以上でなければならない。

$$\sin(\theta_c) = 1/n \qquad (1)$$

【００２１】したがって、プリズム体２Ａ，２Ｂの傾斜面と液晶光学素子３０の表基板とのなす角度を、（９０°－θ_c）以上にしなければならない。一方、液晶光学素子３０の表基板３１の表面に反射膜を形成する場合は（１）式のような制約はないため、プリズム体２Ａ，２Ｂの形成の許容範囲が広い。

【００２２】液晶光学素子３０は、表基板３１、透明な表電極３０Ａ、液晶樹脂複合体層３０Ｂ、非透明で光を

反射し反射手段を兼用する裏電極３０Ｃ、および裏基板３２からなる。裏基板３２側には温度調整器が設けられている。さらに、液晶光学素子を駆動する駆動回路、および温度調整器を駆動制御する電子回路等などからなる。

【００２３】本実施例での場合、液晶光学素子の表基板３１の、例えばガラスと空気との界面を全反射面として用い、表基板３１と反射手段を兼用する裏電極３０Ｃとの間で反射を繰り返し液晶固化物複合体層を４回以上通過させることにより散乱能をさらに向上し、消光比を改善することができる。

【００２４】このとき、図１のように、ガラス性の表基板３１と空気との界面での反射はガラスの屈折率によって定まる全反射が起こるようにする。あるいは、アルミニウムや銀等の金属ミラーや多層誘電体膜などのミラーを形成してもよい。正規反射低減手段としては、表電極３０Ａが形成される表基板３１の面を微細な凹凸が形成されたフロスト面としている。

【００２５】つぎに、本発明で用いられる液晶固化物複合体の構成について概説する。本発明における液晶光学素子では、ネマチック液晶が固化物マトリックス中に分散保持された液晶固化物複合体を挟持した液晶表示素子を用いる。特に、正の誘電異方性を有するネマチック液晶が固化物マトリックス中に分散保持され、その固化物マトリックスの屈折率が使用する液晶の常光屈折率（n_o）とほぼ一致するようにされた液晶固化物樹脂複合体を用いることが好ましい。そして、液晶固化物複合体を、一対の電極付きの基板間に挟持する。

【００２６】ネマチック液晶のn_oと異常光屈折率（n_e）との差である屈折率異方性を△ｎとすると、△ｎは０．１８以上であることが好ましい。また、特定波長λ（μｍ）に対して液晶固化物複合体層の高い散乱能を得るためには、液晶の平均粒子径Ｒ（μｍ）がその波長に応じて揃っていることが好ましい。実際には、△ｎ・Ｒ≒λの関係を満たすことが好ましい。

【００２７】したがって、光エネルギー伝送用のバンドルファイバを用いて可視光の波長帯域（λ＝０．４～０．７（μｍ））の光を変調する場合、全波長域で液晶固化物複合体層での散乱能がほぼ均一になるためには、液晶の平均粒子径Ｒが、

０．４＜△ｎ・Ｒ＜０．７

の関係を満たす範囲に分布していることが好ましい。

【００２８】一方、光通信用単線ファイバを用い、光として非可視光域の半導体レーザダイオードやＬＥＤの近赤外波長域（λ＝０．８～１．６（μｍ））の単一波長の光を用いる場合、または可視光発振のレーザであるＨｅ－Ｎｅレーザや半導体レーザの単一波長の光を光計測用に用いる場合、液晶の平均粒子径Ｒは、△ｎ・Ｒ≒λを満たすような粒径分布の少ない構造が好ましい。

【００２９】この電極付きの基板はガラス、プラスチック、セラミック等の基板上に電極が設けられたものが使用される。本発明では少なくとも入射面側の基板には透明な材料を用いる。さらに平坦で光学的な歪の少ない基板面を形成するにはガラスが適している。

【００３０】それぞれ電極付きの一対の基板間に、液晶固化物複合体を挟持する。この液晶固化物複合体は、電圧の印加により電界が発生し、その電界に応じて液晶分子の配向が変わり、液晶固化物複合体中の液晶の屈折率が変化する。その固化物マトリックスの屈折率が、液晶の屈折率とほぼ一致したときに光が透過し、一致しないときに光が散乱する。この液晶固化物複合体を用いた液晶光学素子は偏光板を用いていないので、光損失の少ない光変調器が得られる。

【００３１】具体的には、液晶表示素子として細かな孔の多数形成された固化物マトリックスとその孔の部分に充填されたネマチック液晶とからなる液晶固化物複合体を用いる。この液晶固化物複合体を、電極基板間に挟持する。その電極間への電圧の印加状態により、その液晶の屈折率が変化し、固化物マトリックスの屈折率と液晶の屈折率との関係が変化する。これら両者の屈折率がほぼ一致した時には透過状態となり、屈折率が異なった時には散乱状態となるような液晶光学素子が使用できる。

【００３２】この細かな孔の多数形成された固化物マトリックスとその孔の部分に充填された液晶とからなる液晶固化物複合体は、マイクロカプセルのような液泡内に液晶が封じ込められたような構造である。しかし、個々のマイクロカプセルが完全に独立していなくてもよく、多孔質体のように個々の液晶の液泡が細隙を介して連通していてもよい。さらに、連通の度合いが高く、液晶が編み目状に連通している状態でもよい。

【００３３】本発明に用いる液晶固化物複合体は、例えば以下のようにして製造される。ネマチック液晶と、固化物マトリックスを構成する硬化性化合物とを混ぜ合わせて溶液状またはラテックス状にする。次いで、これを光硬化、熱硬化、溶媒除去による硬化、反応硬化等させて固化物マトリックスを分離し、固化物マトリックス中にネマチック液晶が分散した状態をとるようにすればよい。

【００３４】使用する硬化性化合物を、光硬化または熱硬化タイプにすることにより、密閉系内で硬化できるため好ましい。特に、光硬化タイプの硬化性化合物を用いると、熱による影響を受けなく、短時間で硬化させることができ好ましい。具体的な製法としては、従来の通常のネマチック液晶と同様にシール材を用いてセルを形成し、注入口からネマチック液晶と硬化性化合物との未硬化の混合物を注入し、注入口を封止した後、光照射をするか加熱して硬化させることもできる。

【００３５】また、本発明における液晶光学素子の場合には、シール材を用いなく、例えば、電極としての透明電極を設けた基板上に、ネマチック液晶と硬化性化合物

との未硬化の混合物を供給し、その後、もう一方の電極つき基板を重ねて、光照射等により硬化させることもできる。もちろん、その後、周辺にシール材を塗布して周辺をシールしてもよい。この製法によれば、単にネマチック液晶と硬化性化合物との未硬化の混合物をロールコート、スピンコート、印刷、ディスペンサーによる塗布等の供給をすればよいため、注入工程が簡便であり、生産性がきわめてよい。

【００３６】また、これらのネマチック液晶と硬化性化合物との未硬化の混合物には、基板間隙制御用のセラミック粒子、プラスチック粒子、ガラス繊維等のスペーサー、顔料、色素、粘度調整剤、その他本発明の性能に悪影響を与えない添加剤を添加してもよい。

【００３７】以上、光重合法による製造方法を示したが、この他にエマルジョン法によってもマイクロカプセル化液晶を形成することもできる。

【００３８】つぎに、その他の構成要件について説明する。液晶光学素子３０の表電極３０ＡとしてはＩＴＯなどの透明電極を酸性液によるエッチングや研磨によりフロスト処理されたガラス性の表基板３１の上に形成している。フロスト処理によって形成された凹凸は、その面での正規反射が最終的に出射側の導光手段５２に到達するのを低減する形状であればよい。

【００３９】したがって、反射面３０Ｃと平行な面が多く存在する矩形状の凹凸は不適切であり、傾斜角を有する斜面の集合体である△状の凹凸が好ましい。この傾斜角は、導光手段５１，５２の有効径、入力インターフェース５５、出力インターフェース５６、液晶固化物複合体層への入射角、反射回数等に関係するが、一般に傾斜角は垂直に近いほど、すなわち鋭い△状の凹凸程不要な界面反射は取り除かれる。

【００４０】しかし、鋭角な程表面積が増大するため、界面反射の割合が増大し、利用できる透過光が減少する。したがって、透過率の著しい低下を招かず、不要な界面反射を低減できる傾斜成分の多い△状の凹凸が好ましい。また、本液晶光学装置は表示素子のように面内特性の均一性が必要でないため、凹凸の大きさ（ピッチ）に関しての制約は厳しくないが、印加電圧に対する透過光量の特性において、オン－オフ動作の場合のようにより鋭い立ち上がりが必要とされる場合は、凹凸の大きさ（ピッチ）は小さいほど好ましい。

【００４１】一方、中間光量を細かく制御したい調光器等の応用にはなだらかな印加電圧に対する透過光量の特性が必要なため、凹凸のピッチすなわち深さを大きな値とし液晶固化物複合体層の厚みが分散している方が好ましい。凹凸面上に形成された透明電極と液晶固化物複合体層との間で生じる界面反射強度をさらに低減するためには、透明電極層の上にSiO_2やMgF_2等の低屈折率層を反射防止膜として形成することが好ましい。また、反射面３０Ｃとしては電極を兼ねてアルミニウム膜を形成したガラス性の裏基板３２を用いた。金属膜以外に透明電極を誘導体多層膜ミラーの上に積層した構造としてもよい。

【００４２】表基板３１の反射面と空気との界面において生じる全反射を利用する場合、表面の異物および汚れは全反射効率を劣化させる原因となるため、表面に表基板材料より屈折率の小さな膜、例えば含フッ素脂肪族環構造を有する重合体（商標：サイトップ）等、を保護膜として形成することが好ましい。

【００４３】さらに、液晶固化物複合体層が透明状態の時は光が表基板３１で全反射される反射面領域は図１に示されるように一部のみであるが、液晶固化物複合体層が散乱状態のときは散乱光は表基板３１の空気との界面のより広い範囲に入射する。このような不要な散乱光を効率よく除去するためには、必要とされる全反射領域以外に黒色塗料などの光吸収体を形成することが有効である。

【００４４】また、液晶光学素子の反射面の裏側に温度センサと電熱ヒータが内蔵された放熱板を接着した。さらに、この放熱板の背後に空冷用ファンを取付け、液晶光学素子が設定温度に維持されるように温度をモニターしながら電熱ヒータと空冷用ファンにより温度調整できるようにした。

【００４５】ハロゲンランプやＸｅランプやメタルハライドランプ等の可視光源を入射側光ファイバ５１に導光し入射光とした。前記の液晶光学素子３０の電極間に１００Ｈｚの矩形波を交流電圧を印加し、実効電圧値を外部回路により変調し液晶光学素子の透過散乱状態を変化させることによって調光器とした。このような構成で作製した本発明の光ファイバおよび透過散乱型の液晶光学表示素子を用いた液晶光学装置を用いて、その光学特性を測定した。その結果を表１にまとめた。

【００４６】表１において、相対的光透過率は比較例を１００％としている。また、測定は恒温度槽内で行われ、温度は液晶表示素子の温度ではなく光学装置の周囲温度を意味し、測定消光比は０℃から５０℃の温度範囲における液晶光学素子の印加電圧値０Ｖと３０Ｖに対する出射側ファイバ５２の光量値比率の範囲を示す。比較例として、実施例１に示した構成の液晶光学素子のうち、表電極３０Ａ面を平坦面とした構成のものに関して同様の光学特性評価を行いその結果を記載した。

【００４７】

【表１】

	不要な正規反射光除去手段	相対的光透過率	消光比	応答速度（ｍｓｅｃ）
実施例１	フロスト面あり	９８％	２５０～２８０	１５
比較例１	フロスト面なし	１００％	３～　１５	１５～２００

【００４８】この結果から、本発明の構成により光損失はほとんど小さいまま、消光比の飛躍的向上と安定性が達成されていることがわかる。したがって、本光学装置を調光器として用いることにより、印加電圧値に対応した出射光量の調整が光量損失が少なく、任意にかつ高速に行うことができる。

【００４９】また、本液晶光学装置は、出射側光ファイバの光出射端を被照明物に向けて設置し、光電子増倍管やＳｉフォトダイオード等の光検出器の電気信号をロックイン増幅器によりＳ／Ｎ比の高い光計測をする場合に必要なファイバ式光チョッパーとして利用できる。従来の回転窓式チョッパーあるいは振動型チョッパーに比べて、小型で高速な光チョッピングが可能となる。

【００５０】反射面３０Ｃはアルミニウムなどの金属反射鏡でもよいし、光学干渉多層膜反射鏡でもよい。前者の場合、反射面が電極も兼ねるため製造が容易であり、かつ構造が複雑化しないで素子が構成できる。後者の場合、多層膜の構成によって熱線を透過し可視光のみを反射するような分光特性を有するコールドミラーを形成することも可能であるし、光通信で用いられる特定の半導体レーザ波長に対して反射率１００％のミラーも形成できる自由度がある。

【００５１】（実施例２）図２を用いて説明する。本実施例では実施例１の構成と異なり、表電極３０Ａと裏電極３０Ｃはいずれも透明電極で、ともにほぼ平坦面である。また、液晶固化物複合体層３０Ｂと反射手段の反射面との距離ｄを充分開けることによって、厚さｔの液晶固化物複合体層３０Ｂと透明な表電極３０Ａおよび裏電極３０Ｂの面との界面で生じる正規反射光の光路を液晶光学素子の面内で生じる正規反射光の光路を液晶光学素子の面内方向にシフトさせ、不要な界面反射光が出射側の導光手段５２に到達しないようにすることができる。

【００５２】このシフト量δは、液晶固化物複合体層３０Ｂへの入射光の入射角θと反射手段の反射面との距離ｄによってδ＝２ｄ・ｔａｎθと記述される。不要な界面反射光を出射側導光手段５２に到達させないためには、シフト量δが液晶固化物複合体層３０Ｂへの入射光の照射幅Ｌ以上であればよい。このようにして、不要な界面反射光を除去するのに必要なシフト量δが定まれば、それに応じて間隔ｄが求まる。液晶固化物複合体層を保持する片側の基板としての機能も考慮すると一定以上の厚みｄが必要となり、一方ｄを大きな値とすると液晶光学素子が大型化するため、実際にはｄ＝０．５～３０ｍｍ程度が好ましい。

【００５３】また、本実施例では光通信情報伝送用のコア径１０μｍの石英系単一モード光ファイバを導光手段５１，５２として用い、屈折率分布型（グレーテッドインデックス）ロッドレンズを入力インターフェース５５、出力インターフェース５６として用いた。光ファイバ導波光は波長１．３μｍおよび１．５μｍ近赤外域の半導体レーザ光を用いた。プリズム体２Ａ，２Ｂは各々図２に示されるように入力インターフェース５５、出力インターフェース５６と液晶光学素子３０の表基板３１に光学接着剤で接合されている。

【００５４】また、液晶光学素子３０の表基板３１の表面の反射面部分のみに導波光の波長帯域の光を９９％以上反射する誘電体多層膜ミラーが形成され、他の表基板３１の表面には光吸収体が塗布されている。本実施例では、表基板３１の表面での反射を全反射ではなく誘電体多層膜ミラーで行うため、（１）式で記述される全反射条件を満たす必要はない。

【００５５】したがって、液晶固化物複合体層３０Ｂでの散乱光や導波光以外の波長光等の不要な導波光が表基板３１の表面で全反射されて一部が導波することを防ぐために、（１）式で定まる臨界角θ_cより小さな入射角で液晶固化物複合体層３０Ｂに入射するようにプリズム体２Ａ，２Ｂの傾斜角を定め、不要な光が液晶光学素子３０内部を導波する割合を減らした。

【００５６】本実施例では、液晶固化物複合体層３０Ｂの厚み約２０μｍとし、表基板３１および裏基板３２を板厚約１ｍｍのホウ珪酸ガラスを用いた。その結果、10^6以上の高い消光比と２ｍｓｅｃ以下の応答速度が安定して得られた。

【００５７】（実施例３）図３を用いて説明する。本実施例では実施例１の構成と異なり、表電極３０Ａの面と裏電極３０Ｃの面はともにほぼ平坦である。裏基板３２の裏面側に設けられた専用の光反射手段９０によって光が反射される。また、液晶固化物複合体層３０Ｂと接する透明な表電極３０Ａと裏電極３０Ｃとは光反射手段９０と平行とされず適当な傾斜角度を付けておくことによって、液晶光学素子３０内部の不要な界面反射を除去することができる。

【００５８】光を集束させずに、ほぼ一対一の関係で伝送せしめるような本発明の場合には基板の平坦面精度がさほど要求されないため、ＰＥＴフィルムのような薄板で安価なフィルム状基板を用い、長尺のフィルム形成技

術を用いても問題がない。

【００５９】本実施例では、その液晶固化物複合体層３０Ｂでの界面の不要な正規反射光が出射側光ファイバ５２に入射して消光比の劣化を招かないように、表電極３０Ａと液晶固化物複合体層３０Ｂと裏電極３０Ｃの各界面と光反射手段の反射面９０とが傾斜するように配置されている。

【００６０】その傾斜角αは、導光手段５１，５２の有効径および入・出力インターフェース５５，５６の焦点距離によって定まる液晶固化物複合体層に入射する平行光の分散角θに対して、θ以上に設定しておけば液晶固化物複合体層の界面で生じる不要な反射光は導光手段５２に入射することはない。

【００６１】光通信用単線ファイバの場合、コア径が２００μm以下と細く、Ｎ．Ａ．も小さいため傾斜角度αは0．１°～１０°の範囲が好ましい。一方、光エネルギー伝送用ファイバの場合には、バンドルファイバ等として用いるので光伝送部のファイバ径は２～２０mm程度と太いため傾斜角度αは１°～２０°の範囲が好ましい。

【００６２】さらに、大きな傾斜角度αとした場合も、界面反射光は除去されるが、液晶固化物複合体層に斜めから入射する光が大半となり、透明時のインデックス・ミスマッチングに伴うヘイズが生じやすく実効的な透過率が低下する。また、傾斜角度αが大きくなると液晶光学素子が厚くなり、装置全体の大きさおよび重量が増加するため、傾斜角度αは上記の範囲にとどめておくことが好ましい。

【００６３】本実施例では、実施例１と同じ有効径５mmのバンドルファイバと焦点距離３０mmの凸レンズを用いているため、液晶固化物複合体層に入射する平行光の分散角θは約１０．６°となり、液晶固化物複合体層を光反射手段の反射面に対して１２°傾斜させた。

【００６４】本実施例では、温度調整をより正確に行い、広い環境温度に対しても光学特性の再現性を確保するため、反射鏡をコールドミラーとし、温度調整器６０として電子制御のペルチェ素子と温度センサが埋め込まれた放熱板を用いた。

【００６５】図３の構成で光学特性を評価したところ、－２０℃から８０℃の広い環境温度において、常時消光比３２０が得られるとともに、印加電圧対光出力特性も温度変化に対して安定した結果が得られた。また、アルミニウム性のものに比べてコールドミラー性の方が１０％程度反射率が高いため、相対的光透過率は比較例１に比べ高い値となった。

【００６６】さらに、以上説明した実施例の構成の液晶光学装置において、液晶光学素子３０を反射面側（裏基板３２の裏側）から強制温度制御でき得る構成となっている。強制温度制御法としては、放熱板を装着して空冷ファンで冷却する。あるいはペルチェ素子、電熱ヒータと温度センサを装着して、一定の温度に維持されるよう加熱・冷却による温度制御することもできる。

【００６７】（実施例４）本発明の実施例４を図４を用いて説明する。本実施例では、光通信用単線光ファイバを用い、入射側光ファイバ５１および出射側光ファイバ５２、Ｖ型の全反射面を備えたプリズム体３、光変調部として機能する反射型の液晶光学素子３０、そして温度調整器６０からなり、さらに液晶光学素子を駆動する駆動回路および温度調整器６０を駆動制御する電子回路などからなる。

【００６８】また、液晶光学素子３０とプリズム体３と、ロッドレンズからなる第１のインターフェース５５または第２のインターフェース５６などから構成され、各光学要素は光学接着剤で一体に接着されている。

【００６９】液晶光学素子３０の光入射面もしくは出射面側の透明な表電極３０Ａ（ＩＴＯなど）が形成される基板３１のガラス面はフロスト処理されている。反射面としては入射光である特定のＬＤ（レーザダイオード）やＬＥＤの発光波長を反射する光学干渉多層膜ミラーが成膜された裏基板３２上に透明な電極を形成し、対向基板を形成した。液晶光学素子の入射側および出射側の光ファイバとしては、ＦＣコネクター接続型の石英系ファイバで、コア直径５０μmの多モード伝送用ステップ型屈折率分布光ファイバを用いた。

【００７０】入力インターフェースおよび出力インターフェースとして、それぞれに直径＝１．８mm、ピッチ＝１／４、レンズ長＝４．７３mmの波長８３０nmＬＤ用グレーテッドインデックス型のロッドレンズ（ＮＳＧ：セルフォックレンズ）を用いた。

【００７１】プリズム体としては光学ガラスのＢＫ７を用い、入力インターフェース５５（ロッドレンズ）から出射されたほぼ平行な光を一方のプリズム全反射面３ａで反射したのち反射型の液晶光学素子３０に約１８°の入射角で入射させ、反射手段（裏電極３０Ｃが兼用される）で反射した正規反射光をもう一方のプリズム全反射面３ｂで反射したのち出力インターフェースにより導光している。この光は、さらに出射側の光ファイバ５２の端面に集光され、出射光となる。

【００７２】本実施例では、実施例２と同様に、温度調整器６０として電子制御のペルチェ素子と温度センサが埋め込まれた放熱板を用い、広い環境温度において、常時安定した光学特性が得られるようにした。このような構成で作製した本発明の光ファイバおよび透過散乱型表示素子用いた液晶光学装置を用いて、その光学特性を測定した結果を表２にまとめた。表２において、相対的光透過率は比較例を１００％としている。

【００７３】また、測定は恒温度槽内で行われ、温度は液晶表示素子の温度ではなく光学装置の周囲温度を意味し、測定消光比および応答速度を、－２０℃から６０℃の温度範囲において液晶光学素子の印加電圧値０Ｖと１

００Ｖに対して評価した。

【００７４】比較例として、従来構成である液晶光学素子の光入射側のＩＴＯ電極面を平坦面し、温度調整器６０を搭載しない構成のものに関しても同様の光学特性評価結果を記載した。

【００７５】

【表２】

	不要な正規反射光除去手段	相対的光透過率	消光比	応答速度（ｍｓｅｃ）
実施例３	傾斜角度	９９％	３００００	１．５
比較例２	な　し	１００％	５～２５	１．５～１００

【００７６】この結果から、本発明の構成により光損失はほとんどないまま、消光比の飛躍的向上と安定性が達成されていることがわかる。したがって、本光学装置を光通信用の可変光減衰器として用いることにより、印加電圧値に対応した出射光量の調整が光量損失が少なく任意にかつ高速に行うことができる。

【００７７】本実施例では、Ｖ型の全反射面を有するプリズム体３を用いた構成で記したが、他の構成でもよい。例えば、球面或いは非球面などによって光路を折曲げてもよい。また、プリズム体３の全反射面の形状と光ファイバのコア径の比率を変えた構成とすることによって、消光比を更に改善することもできる。

【００７８】（実施例５）実施例５を図５を用いて説明する。本実施例では、入力用光ファイバ、入力用インターフェース５５（ロッドレンズ）からプリズム体４に出射されたほぼ平行な光を台形形状のプリズム体４によって反射型の液晶光学素子３０に適当な入射角で入射させることにより、裏電極３０Ｃで全反射され、再びプリズム体４の上側全反射面４ａで全反射される。そして、適当な位置にプリズム体４を配置すると、液晶光学素子の反射面と全反射面とで反射を複数回繰りかえした後、光が出射側の出力用インターフェース５６に出力される。

【００７９】このような構成で、光を４回以上液晶固化物複合体層を通過させることによって、２回だけ通過するような従来例での構成に比べてさらに消光比を向上させることができる。図５では液晶固化物複合体層を４回通過する場合を記しているが、プリズム体４の長さ（上面４ａの左右方向の長さ）および入射角を適当に変えることにより、通過回数を２の倍数で任意に変えることができる。

【００８０】反射型の液晶光学素子３０は実施例１と同じ構成でもよいし、実施例２または実施例３のように液晶固化物複合体層３０Ｂに接して反射面を形成せず、外付け反射面による光反射手段を設けてもよい。この場合、正規反射低減手段として、表電極と裏電極の両面ともフロスト面とするか、実施例２のように液晶固化物複合体層に光反射手段の反射面との間隔を設けるか実施例３のように光反射手段の反射面と液晶固化物複合体層３０Ｂとを適当に傾斜させる（図３参照）ことにより、液晶固化物複合体層３０Ｂと電極面との界面反射を除去すればよい。

【００８１】凹凸の大きさ（ピッチ）は２～２００μｍ程度が好ましく、凹凸の深さ（十点平均深さ）Rz は０．１～１０μｍ程度が好ましい。また、このように液晶固化物複合体層に対して光が斜め方向から入射する場合、透明時の液晶とのインデックスマッチングが光入射角度において最も最適（すなわちヘイズの少なくなるような）組み合わせにすることが好ましい。

【００８２】以上、実施例について説明を行ったが、次に各部の大きさなどについて概略説明を行う。光エネルギーを伝送する場合には、光源としてハロゲンランプ、メタルハライドランプ、Ｘｅランプ等が用いられ、いずれも発光長が２～１０mm程度あるため、集光手段を用いて効率よく集光し、ファイバに導光するためには３～１０mm程度のファイバ直径が必要となる。

【００８３】また、光源の大きさは、長さ３～１０ｃｍ（１０Ｗ～５００Ｗクラス）から１０～３０cm（５００Ｗ～３ｋＷ）程度の幅があり、光源の種別に応じて集光鏡の大きさも合わせせることになる。そして、液晶光学素子の大きさは用いる集光手段（楕円鏡やレンズなど）の大きさ、例えばその焦点距離や有効径とファイバのＮ．Ａ．等に応じて決まるが、上記光源を用いる場合は、およそ対角１～３０ｃｍ程度と考えられる。

【００８４】通信や光計測等の目的に用いる場合には、光の入射口径は１mm以下であり、レーザダイオートやＬＥＤの発散光を集光するためにレンズを用いても、その直径は１ｃｍ以下となる。光通信用単線ファイバの光伝送部コア径は２００μｍ以下程度なので、液晶光学素子の大きさは、およそ１～５ｃｍ程度となる。

【００８５】

【発明の効果】以上の如く、本発明によれば、電気的に散乱状態と透過状態を制御しうる液晶光学素子と光反射手段とにより、光源から出射された光を液晶光学素子の光変調部分に複数回通過させるため、１回しか透過しない場合に比べて実効的散乱能が飛躍的に向上する。

【００８６】また、正規反射光低減手段として、液晶固化物複合体層と透明電極との界面に凹凸を形成する、または、液晶光学素子の液晶固化物複合体層と光反射手段

との間隔ｄを液晶固化物複合体層の厚さｔに対して１０倍以上とするあるいは液晶固化物複合体層と反射面とを平行とせず傾斜を付ける、さらには、空気との素子界面において液晶固化物複合体層を通過しないで直接光ファイバに入射する界面反射面部分に黒塗料を塗ることによって、バックグラウンドノイズの主因である界面反射光を低減している。

【００８７】その結果、印加電圧に応じた可変調光機能における消光比およびそのダイナミックレンジの向上が達成された。また、構成上液晶光学素子の片面に温調器を設置することができるため、強制的温度制御により、周囲環境温度に関係なく常に液晶光学素子の最適特性が発現される温度に保つことができるようになり、安定した調光および光シャッタリングが実現した。

【００８８】具体的な例として、高速シャッター機能を有する照明用光源として、ストロボ照明がある。すなわち、高速撮影が可能となる。例えば、シャッター速度が１ｍｓの場合、３６０ｋｍ／ｓの速度で移動する物体に照射すれば、１ｃｍの移動平均画像が記録される。

【００８９】また、高速移動物体を連続的にシャッタリング照明して撮影すれば、軌跡がステップ状に記録される。シャッタータイミングを任意に可変でき、高速追従性があるというプログラマブルな特質を利用した例として一定周期でオン－オフする計測用光源として用い、その周期の信号光だけを増幅し、検出することによって微弱な信号光でも、またはノイズ光の多い環境でも、Ｓ／Ｎ比の高い計測が可能となる。

【００９０】また、本発明においては光が空気中を通過することなく、全て光学的に屈折率が近くせしめられた固体媒質だけを通過するので損失が小さくなる。

【００９１】その結果、本光学装置を調光機能付き照明装置、あるいは光シャッタリング機能付き照明装置として光計測に利用することができるようになった。特に、ロックインアンプ用光チョッパー等のように光検出装置と同期を取ってシャッタリングを行うことによりＳ／Ｎ比が改善された。また、光通信分野においても、従来より用いられていた固定減衰率の光減衰器が、印加電圧調整により減衰可変な光減衰器を得ることができるようになった。

【図面の簡単な説明】

【図１】本発明の実施例１（凹凸面）の液晶光学装置の断面の模式図。

【図２】本発明の実施例２（厚み）の液晶光学装置の断面の模式図。

【図３】本発明の実施例３（傾斜）の液晶光学装置の断面の模式図。

【図４】本発明の実施例４（Ｖ型プリズム）の液晶光学装置の断面の模式図。

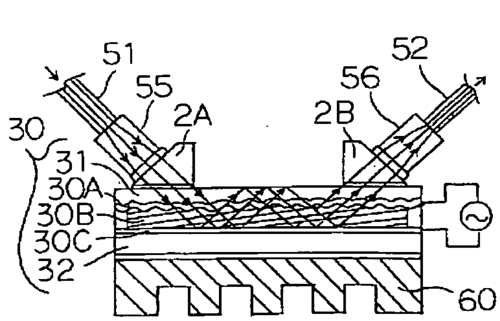
【図５】本発明の実施例５（台形プリズム）の液晶光学装置の断面の模式図。

【図６】従来例における構成を示す平面図。

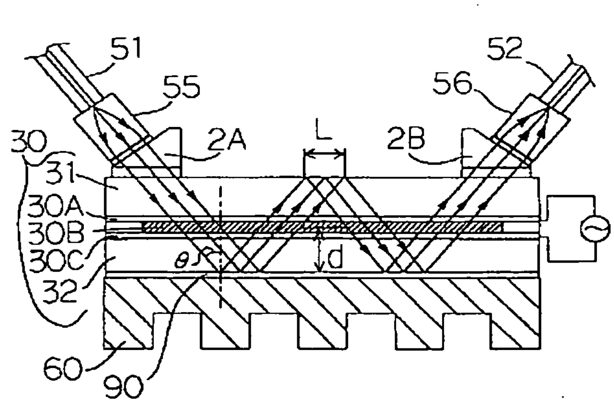
【符号の説明】

２Ａ：入力側プリズム体
２Ｂ：出力側プリズム体
３０：液晶光学素子
３０Ａ：表電極
３０Ｂ：液晶固化物複合体層
３０Ｃ：裏電極
３１：表基板
３２：裏基板
５１：入力側光ファイバ
５２：出力側光ファイバ
５５：入力側インターフェース
５６：出力側インターフェース
６０：温度調整器

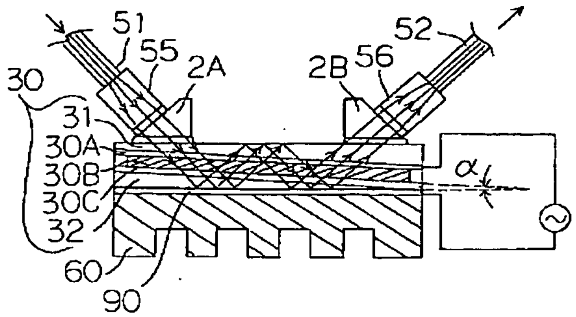
【図１】



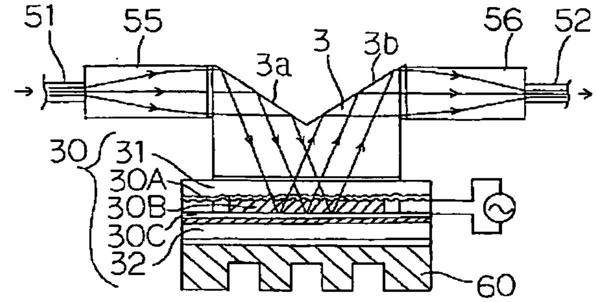
【図２】



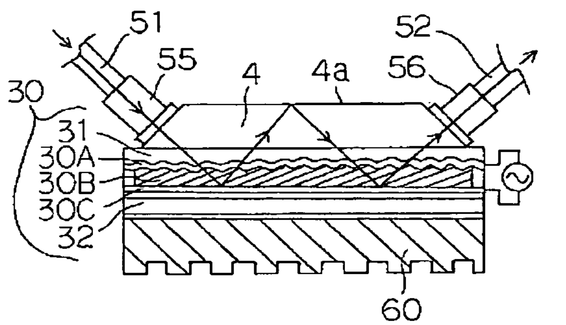
【図3】


51
55
2A
2B
56
52
30
31
30A
30B
30C
32
60
90
α

【図4】


51
55
3
3a
3b
56
52
30
31
30A
30B
30C
32
60

【図5】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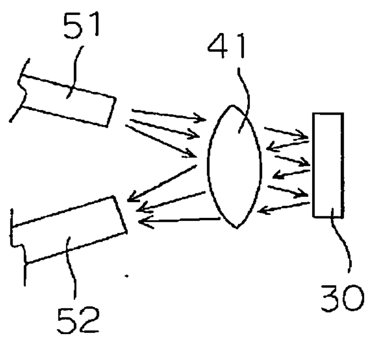
55
4
4a
56
52
30
31
30A
30B
30C
32
60

【図6】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41
52
30